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SPONDYLOLISTHESIS*

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INTRODUCTION

Among the various deformities of the human spine spondylolisthesis occupies a very modest position, being generally relegated to the distant background. Text books of Orthopaedic Surgery devote very few lines to the subject.† The information given is a repetition of the rather obscure origin of the term spondylolisthesis—"slipping of the vertebra"—without a full consideration of the pathogenesis of this curious condition. The immediate proximity of the vertebral displacement to the pelvis and its grave influence on the pelvic measurements long ago determined the recognition of the "spondylolisthetic pelvis" as an additional entity among the pathologic conditions of the pelvis familiar to obstetric physicians. The rarity of the condition, however, resulted in the labelling of each separate specimen by the name of the town or museum to which it belonged.

*This paper was forwarded for publication to the Editorial Secretary of the British Orthopaedic Association. The original illustrations, and particularly the radiograms which had been obtained by the authors under conditions of great difficulty, have been re-drawn by Miss M. Greg, a student of the Manchester University Medical School.

†Since these words were written the authors have received the new textbook of Sir Robert Jones and the late Professor Lovett. This work contains a brief but comprehensive description of the deformity and its etiology.

There has been very little written on the significance of this condition either from the point of view of the general pathology of the vertebral column or from its influence on the statics of the spine as a whole. Our conception of the lesion, however, is becoming more definite with the publication of numerous clinical observations. With the experience gained during recent years it is desirable to emphasize that spondylolisthesis is a lesion of more frequent occurrence than hitherto supposed, and it is very probable that cases of spondylolisthesis have been wrongly diagnosed as traumatic or tuberculous spondylitis or as more obscure conditions of the vertebral column. Having met with an obvious case of spondylolisthesis in which the clinical features were well marked we were considerably aided in the recognition of further cases which later came under observation. We have at present about ten cases at our disposal, but will present only those in which there exists no doubt as to the accuracy of the diagnosis. Our deductions will be reinforced also by the study of the three most instructive anatomic specimens which we were able to obtain.

The names of Rokitansky, Spaeth, Seifert, and Kiwich v. Rotteran were early associated with this form of spinal derangement, and although the exact nature of the lesion was at first obscure, the term "spondylolisthesis" applied to the condition by Kilian has remained unchanged up to the present time. The term signifies the *gradual* forward "slipping" of the last lumbar vertebra in contrast to a sudden traumatic dislocation of the same vertebra at the lumbo-sacral articulation.

Much has been written concerning the etiology of the lesion and many different theories have been propounded to explain its occurrence. Between the years 1838 and 1892 eighteen spondylolisthetic pelves were discovered and described. That different opinions and theories were deduced is probably due to the unsatisfactory conclusions drawn exclusively from the examination of museum specimens. Some of these were not macerated and generally they represented the terminal stage of the condition. On one point there was apparently general agreement—the "slipping" affected only the anterior part of the fifth lumbar vertebra, there being no real unlocking of the interarticular joints. A sagittal elongation of the vertebra and increase of the antero-posterior diameter of the neural arch was therefore assumed. To meet this accepted fact various theories were advanced. Lambl of Warsaw, whose careful observations were the chief feature of the literature of the subject in the fourth decade of the last century, was of the opinion that spondylolisthesis was a congenital malformation remotely connected with foetal hydrorrachis, traces of which remained in the form of widening of the medullary ring.

While recording such theories of the etiology of the lesion as the disappearance of the inter-vertebral disc (Rokitansky), local softening of the bone and cartilage (Kilian), arthritis of the lumbo-sacral articulation (Strasser), attention should be paid to the hypothesis of Arbuthnot Lane, who suggested the possibility of the condition being an acquired deformity due to excessive weight with thinning and loss of continuity in the neural arch. Neugebauer, a former pupil of Lambl, made an exhaustive study of the subject and his name is inseparably associated with the evolution of our knowledge concerning its etiology. He notes that in the majority of spondylolisthetic pelves there was a defective ossification of the laminae of the fifth lumbar vertebra. The degree of defect varied in different specimens from the formation of incomplete "cracks" to complete *non union* of the arch with the formation of a pseudarthrosis (Moscow and Vienna pelves and others). Having examined a series of normal skeletons, Neugebauer found that this imperfect ossification existed in five per cent. of the specimens, and in the majority of cases affected the fifth lumbar vertebra. In accordance with these findings and basing his considerations on embryological data, Neugebauer formulated his theory that spondylolisthesis was a static or traumatic deformity of the spine favoured by the imperfect ossification of the laminae of the fifth lumbar vertebra. He did not entirely reject the theories of Strasser or Lane. In its final form the theory of Neugebauer is best expressed in his own words, "We recognize nowadays three causes of the 'slipping':

"1. Interarticular spondyloschisis—uni- or bi-lateral of the vertebral arch, the result of imperfect ossification or of fracture.

"2. Primary arthritis of the lumbo-sacral articulations. (Strasser.)

"3. Static (or pressure) deformity of the normal vertebra by a prolonged physiological strain. (Lane.)"

Subsequent observations have rendered two of these theories untenable.

The writings of Chiari disclose a very exhaustive anatomico-pathologic study of this lesion. This investigator reviews the existing theories and in addition furnishes detailed descriptions of two dry pelves found by him in the Prague museum under the names of "asymmetrical pelvis" and "ankylosis of hips with dislocation." Both pelves presented the features of spondylolisthesis with symmetrical non-union of both laminae (spondylolysis). (In a postscript Chiari describes a severe case of spondylolisthesis in which the under surface of the body of the last lumbar vertebra was

looking directly backwards into the cavity of the pelvis.) Among the details of the pathologic findings in these specimens mention should be made of the presence of thickening and partial synostosis between the third and fourth lumbar vertebrae, a malformation of the lumbo-sacral articulation with forward displacement of the left lower articular process and ankylosis on the right side. There was no interruption in the continuity of the interarticular portions of the laminae, although their anterior segments showed a distinct downward bending. A consideration of these findings inclined Chiari to regard the condition as being caused by abnormal relations of the lumbo-sacral inter-articular processes. This assumption may be strengthened by a study of some details overlooked by Chiari. The examination of one specimen revealed congenital non-union of the right fourth, and left third dorsal arches. The corresponding drawing shows a defect in the ossification of the posterior wall of the sacral canal. Taking into consideration the above mentioned defects in the development of the spine, one may assume some pre-existing condition of defective ossification of the vertebral arches in the last case quoted by this investigator, although there is no evidence of a distinct hiatus. Chiari, basing his deductions on observations of various cases of fracture of the spine, inclined to the theory of defective ossification as the prime factor in the production of spondylolisthesis. He did not, however, reject the pressure theory of Arbuthnot Lane. He concluded that the condition may be regarded as the final result of various etiologic factors and emphasized that the study of spondylolisthesis in its early stages might elucidate the etiology of this spinal deformity.

The slow progress made in the study of spondylolisthesis is due to the fact that clinical investigations and anatomico-pathologic research on the subject have not proceeded *pari passu*, owing to the condition being seldom recognized during life. The scanty and uncertain data derived from the examination of old museum specimens preserved under various titles do not really assist the clinician. Further, the many theories advanced as to the cause of the condition tend to confuse our conception of its pathology.

CLINICAL PICTURE

As previously noted obstetric physicians have been the pioneers in the study of this lesion. For half a century they monopolized the literature on the subject, with the result that the opinion became prevalent that spondylolisthesis was met with only in females. Occasional communications during the last two decades have shown that the condition is also found in the other sex, but many of the clinical reports are incomplete.

The developments of radiographic technique have now placed the condition as a very definite clinical entity.

The clinical picture of spondylolisthesis has been carefully recorded by Kilian, Breisky, Neugebauer, and others. The symptoms may be briefly summed up as follows. Generally after a single or repeated trauma, or sometimes without previous injury, a curvature of the spine develops gradually, accompanied by pain referred to the lumbar region and radiating down into both lower extremities. The onset of the condition generally occurs after puberty and is often first recognized in women in connection with parturition. The most prominent clinical sign of this condition is the characteristic profile appearance of the patient. There is an apparent shortening of the trunk giving an appearance as if the spine had been "telescoped" into the pelvis. In accordance with this there is generally a more or less well-marked transverse furrow encircling the trunk in the region of the loins, producing folds of skin which in the female may project down over the pubis and cover the external genitalia. A definite hollow in the lower lumbar region may be easily recognized by inspection. Palpation determines the depth of the hollow and defines its position just above the first spinous process of the sacrum. The prominence of the postero-superior angle of the sacrum is easily felt and there is an increased interval between this and the spinous process of the last lumbar vertebra, which is apparently displaced upwards and forwards. Difficulty will sometimes be encountered in determining the exact spinous process bounding the upper margin of the hollow, which may be filled with a thick layer of soft tissues. The process palpated may be the fourth or fifth. Above this the spinous processes are normally arranged. The difference between the aggravation of a normal lordosis and the lordotic hollow of spondylolisthesis should be easily appreciated. The "slipping" of the vertebra produces an angulation rather than a curve. The normal pelvic tilt is diminished and the anterior superior spines are apparently therefore rotated backward through a sagittal arc. A vaginal examination reveals diminution of the antero-posterior diameter of the pelvic inlet. In severe cases there may be complete narrowing (pelvis obtecta) by the displaced vertebral body which may be felt projecting above the sacral promontory. According to Breuss and Koliski no other serious abnormalities of the pelvis are noted. As the condition generally develops in adults the symptomatology is usually sufficiently striking to point to a correct diagnosis, although diagnostic errors have been made by Neugebauer and others. Some authors lay stress on another symptom which may be of considerable significance, viz: the presence of a waddling gait with widely

spread legs. Kleinberg recently described an altered gait in a severe case of traumatic spondylolisthesis but our observations have not enabled us to confirm his statement.

As previously mentioned, the special obstetric interest of spondylolisthesis created the impression that this was a condition entirely confined to the female sex. The fallacy of this conclusion need not be emphasized. Our own observations are sufficiently conclusive, but nevertheless records of spondylolisthesis occurring in the male sex are singularly few. One of the first publications on this subject is associated with the name of Codivilla (1908). The case is briefly described, but the age of the patient is not mentioned. The causal factor, according to the author's opinion, lay in division of the fifth lumbar vertebra into two parts owing to defective ossification. The article is illustrated by an anatomic specimen of a similar vertebra and by a radiogram. Brandenburg (1910) has published details of a case of spondylolisthesis occurring in a male aged seventeen years. The deformity developed gradually, with no relation to trauma. The description of the case lacks clearness and the interpretation of a schematic reproduction of the radiogram is far from convincing. MacCordick, in 1912, described a case of spondylolisthesis of traumatic origin in a man. Post-mortem examination after death from intercurrent illness three years later revealed non-union of the vertebral arches (spondylolysis) and evidences of fracture of the vertebral body. This latter feature and the absence of anterior dislocation of the body of the vertebra preclude this case being accurately described as one of spondylolisthesis. Two most convincing cases of traumatic spondylolisthesis occurring in men of fifty-five and thirty-five years have been quite recently described by Kleinberg. The minute details of the clinical picture given dispel any doubt as to the accuracy of the diagnosis, but the author's ideas of the anatomic basis of the lesion are open to debate. In accordance with Byron Darling's assumption, Kleinberg admits the possibility of a bilateral forward subluxation of the fifth lumbar vertebra on the sacrum, basing his conclusions on an antero-posterior radiogram of his second case. As this radiogram has been retouched with pencil it carries less conviction. The lateral view of the same case—also retouched—shows definite non-union between the body and neural arch of the fifth lumbar vertebra, the former being tilted downward and forward. The idea of a pre-existing malformation of the vertebra is not considered by this author, who speaks of a possible crushing of the vertebra in addition to subluxation. The lateral processes of the fifth lumbar vertebra, according to the writer, appear larger and more irregular than normal and he concludes that they have

been fractured, a separation thus occurring between the anterior and posterior components of the vertebra. The interpretation of these signs as signifying a traumatic spondylolisthesis, put forward by Kleinberg, does not quite coincide with the theory of the etiology of the condition enunciated by Neugebauer and others. Kleinberg writes in discussing the case, "It cannot be denied that subluxation was rendered possible by the existence of the maldevelopment of the first sacral segment, but in this case at any rate we have no evidence of the previous existence of such a congenital defect." On the other hand, the lateral view of the author's second case with incomplete ossification of the vertebra and tilting of the anterior segment is strongly in favor of the occurrence of typical spondylolisthesis, secondary to the pre-existing spondylolysis as pictured by Neugebauer, Lambl, and other authors. The comparatively slight inconvenience caused by the dislocation is thus explained.

As far back as 1855 Robert proved by experiment that a subluxation of the fifth lumbar vertebra *in toto* was impossible without serious damage to the lumbo-sacral articulation and to the strong and complex ligaments which maintain the continuity and stability of the vertebral column at this level. After sawing through the inter-articular portions of the laminae the dislocation was easily produced. A fifth lumbar vertebra with a typical congenital malformation equivalent to the result of Robert's operation has been described by Putti. Our assumption that congenital spondylolysis favours the production of subluxation from trauma leads to a further disagreement with Kleinberg in the interpretation of his radiograms, the appearances of which, it may be added, coincide with ours. In explanation of the presence of the sacral hollow, Kleinberg assumes that the fifth lumbar spinous process becomes displaced forward and is anterior to its normal position. We hold that the hollow is produced mainly by the *upward* displacement of the fifth spinous process which has become more mobile owing to the non-union of the laminae with the vertebral body, and represents the posterior end of a lever, having the lumbo-sacral articulation as its fulcrum. The upward excursion of the spinous process is controlled by the interspinous ligaments. It can easily be imagined that the forward and downward movement of the vertebral bodies overlying the dislocated fifth lumbar vertebra must produce and exaggerate the upward tilting of the mobile fifth spinous process. The spinous process thus tilted upward forms with the laminae a figure ⅄. The fourth and even the third lumbar spinous processes may undergo the same displacement in a lesser degree, as is shown in our own radiographs. This rotation of the sound fourth lumbar vertebra

on a transverse axis is also demonstrated by the distinct oval shaped outline of the base of the corresponding vertebral body.

The significance of these signs will be better understood by a comparison of our pictures with an antero-posterior projection of a normal fifth lumbar vertebra as given by Fisher. The evidence given by the radiogram, as we interpret it, must be accepted as only indirect proof of the presence of a pre-existing congenital deformity. We agree with Putti that a congenital separation of the posterior from the anterior segment of the lamina can never be demonstrated radiographically. The indistinct thickening of the outline of the shadows in the region of the supposed separation, as shown in our pictures, points to a deforming process surrounding the pseudarthrosis.

But conclusive additional evidence of the presence of spondylolisthesis is derived from abdominal palpation. This examination is of especial value in cases occurring in the male sex. The bowel having been emptied by purgatives and enemata, it is possible with practice to palpate the protruding body of the fifth vertebra partly overhanging the sacral promontory and forming a projection below which the fingers slip into the pelvic cavity.

The importance of a further clinical sign described by one of us (Tchirkin) should be emphasized as pathognomonic of acute spondylolisthesis. We do not find it mentioned by other writers on the subject. The presence of this sign may be explained from a mechanical point of view as due to the accommodation of the spine to the sudden change in contour, and as a compensation for the static deformity produced by the forward dislocation and tilting of the fifth lumbar vertebral body. As previously mentioned the connection between the dislocated body and the overlying segment of lumbar spine remaining intact, the latter follows the downward and forward movement of the dislocation. The body is then thrown backwards to maintain the position of the centre of gravity, and a lordotic curve is produced. This lordosis is associated with a *compensatory forward bend of the spine* in the region between the flexible lumbar and rigid dorsal vertebrae. We have been able to identify traces of this nearly constant accessory sign, in the form of a *slight kyphosis* at the dorso-lumbar junction—a prominence of the first lumbar spinous process. Being a frequent finding in our observations, this sign may be regarded as pathognomonic in the clinical picture of spondylolisthesis of recent origin. Its presence has served to confirm our diagnosis in doubtful cases. We are not at present able to offer a feasible explanation of the pathologic anatomy of this sign. It may be caused by an overstretching of the

interspinous and other ligaments, with partial compression of the vertebral bodies, the first lumbar vertebra undergoing a slight backward dislocation.

DESCRIPTION OF CASES

The following cases chosen from a series under our observation during the past two years may be taken as examples illustrating the history and clinical course of spondylolisthesis.

FIG. 1

Female 19 years of age. Typical figure of spondylolisthesis.

FIG. 2

Side view of the same patient.

CASE 1. Girl aged 19 (Figs. 1 and 2). Always enjoyed good health. When seven years of age she fell from a horse, with no serious results except occasional pain in the back and elbow. Three years later a deformity of the spine with prominence of the sacrum was noticed, unaccompanied by complaints of pain or fatigue. At the age of seventeen, having taken part in heavy household duties, she began to feel pains in

the loins, stiffness of the back, and a sense of fatigue. The deformity of the spine became gradually more evident.

Present examination reveals the following features: Height, 160 cm; trunk rather shorter than normal, with slight scoliotic bend to the left in the dorso-lumbar region. The upper part of the sacrum is prominent, with a hollow nearly 4 cms. deep above it. Lateral movements of the spine are free, but flexion is restricted. There is increased lordosis in the lumbo-dorsal region, the anterior superior spines seem to be on a more posterior plane and the pelvic tilt is less marked than normal. The angle of the right scapula lies at a lower level than on the left side. A deep furrow is present, encircling the waist. This groove commences on both sides of the vertebral column and crosses the abdomen at the level of the umbilicus. The appearance of the body from behind is suggestive of "telescopic shortening" of the trunk. The pelvic limits are well defined, but there is no undue prominence of the trochanters. The two lowest ribs on the left side are hidden behind the iliac crest and the right ilio-costal space is about two fingers in depth. Pelvimetry gives the following results:

(a)	Intertrochanteric diameter	34 cm.
(b)	Interspinous	28 cm.
(c)	Intercristal diameter	32 cm.
(d)	Longitudinal diameter	10.5 cm.
(e)	Transverse	8.5 cm.
(f)	Conjugate (external)	20.5 cm.

The anteroposterior radiogram (Fig. 3), although not very distinct, gives positive evidence of spondylolisthesis. There is a considerable degree of upward tilting of the spinous processes of the fourth and fifth lumbar vertebrae, which are arranged in tile-like fashion. The shadows of the laminae and spinous process of the fifth lumbar vertebra are clearly defined, their density being similar to that of the sacrum. Examination of the overlying spine shows the shadows becoming less defined, those of the fourth lumbar vertebra remaining clearly visible. The remarkable density of the shadows of the posterior part of the fifth lumbar vertebra is positive evidence against the condition being a total dislocation of the vertebra. The shadow of the tilted body coinciding with that of the sacrum, its characteristics are not easily defined—a semicircular line, convexity downwards, suggests the position of the body in the pelvic cavity. Deepening of the shadows in the region of the pedicle would seem to indicate increased bony deposit in the region of the pseudarthrosis. The hiatus between the sacrum and uplifted laminae of the fifth lumbar vertebra is asymmetrical, the lamina on the left side being shorter than on the right. This factor provides an explanation of the presence of scoliosis in this case. We regret that owing to difficulties in radiography we are unable to present a lateral roentgenogram of the spine. In any case a clear lateral view of this condition is not easily obtained on account of the shadow of the ilium obscuring the view of the subluxated vertebra. The actual photograph of the patient, however, shows an excellent picture of the characteristic deformity of the trunk. It is submitted as being as typical as any case recorded in the literature of the subject. The pelvic measurements in this case almost coincide with those described by Neugebauer in his case No. 14 (Spondylolisthesis and Spondylolysis, 1892). Our case was demonstrated by one of us (H. T.) to the Fifteenth Congress of Russian Surgeons at Petrograd in 1922.

Case 2. Female, age 31 years. Married. No history of previous illness or

accident of importance during childhood. Painful menstruations lasting three days commenced when patient was 19. For the past five years patient has had intermittent pains in the loins, treated as a neurosis. First pregnancy at twenty-four, during which

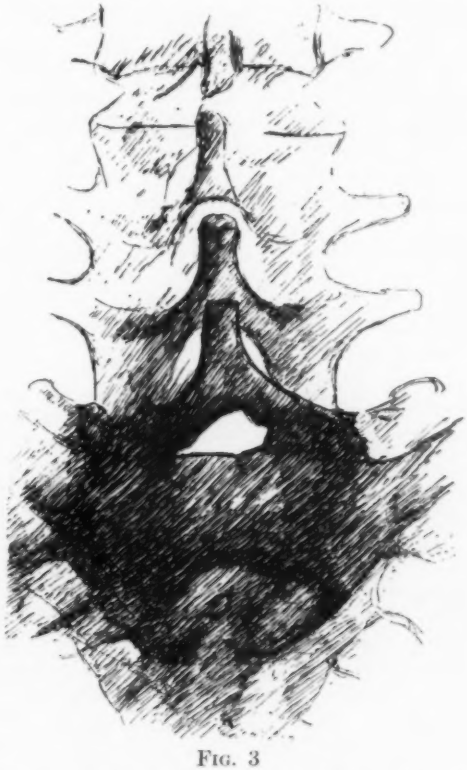

FIG. 3

Tracing of a radiogram of the lumbar spine of Case 1.

Note (a) the upward tilting of the spinous processes of the fourth and fifth lumbar vertebrae.

(b) the increased density of the laminae of the latter vertebra.

(c) the semicircular outline of the displaced body of the fifth lumbar vertebra superimposed on the sacral shadow.

(d) the increased density in the region of the supposed laminar pseudarthrosis.

a prominence of the lumbar spine was noted. The period of pregnancy was of normal duration and twins weighing five pounds and six pounds, who died soon after birth, were manually delivered. The diagnosis of contracted pelvis being established, the patient was advised to avoid further pregnancies, and during the next two years there

were two abortions. The pains increased and the lumbar deformity became more pronounced and the condition was diagnosed as spondylitis by the attending physicians. In April, 1923, the patient was admitted to the Orthopaedic Department of the Medical Academy.

Clinical report: General health good. Examination reveals symptoms analogous to those of the previous case. Shortening of the trunk present as if due to "telescoping" into the pelvis; ilio-costal distance is one finger. There is a dependent abdomen and a deep furrow encircling the waist. Movements involving flexion of the spine are restricted. There is a deep hollow visible in the lower part of the spine, palpation of which above the sacrum is accompanied by tenderness. The prominent body of the fifth lumbar vertebra is easily felt through the abdomen. Pelvimetry by Dr. Tavildaroff gives the following measurements:

(a)	Interspinous diameter	26 cm.
(b)	Intercristal	29 "
(c)	Intertrochanteric	32 "
(d)	External conjugate	20 "
(e)	Antero-posterior diam. outlet pelvis	10 "
(f)	Transverse outlet of pelvis	8.8 cm.
(g)	Michaelis rhomboid	15 x 8 "
(h)	Diagonal conjugate diameter not ascertained.	

Digital examination reveals increase of elevation of sacral promontory. According to Dr. Tavildaroff, this case must be accepted as a typical example of spondylolisthesis. The antero-posterior roentgenogram (Fig. 4) shows upward tilting of the spinous processes of the lower three lumbar vertebrae, especially of the fifth. The visible gap between the upturned arch of the last mentioned vertebra and the sacrum is much larger in this case than in the previous one, the deformity here being more severe and of longer standing. The cause of the hollow above the sacrum is well explained by a study of this radiogram, the distinct outlines of the positions of the spinous processes of the fourth and fifth lumbar vertebrae being conclusive evidence against their forward dislocation. Owing to the lordotic deformity the shadows of the third lumbar vertebra are faint. The patient escaped further observation, although she gave consent to being photographed.

Case 3. Male, aged 36 years. Clockmaker by trade. Admitted to the clinic in April, 1923, complaining of pains in the lumbar region. Previous illness—Typhoid, 1905. He enlisted in the army in 1916, being then in perfectly good health. After lifting a beam during the preparation of artillery shelters he felt a sudden pain in the back which increased after every physical exertion. The symptoms subsided after two months hospital treatment, but on his return home light physical strain exacerbated the pains, which became worse and rendered him quite unfit to undertake any exertion.

On admission to the clinic the patient presented the usual symptoms of spondylolisthesis. In the upright position he maintained a backward list of the trunk, which seemed slightly shortened. Patient was lame on one side. There was a distinctly-marked hollow above the sacrum. Abdominal palpation revealed a prominence of the fifth lumbar vertebra, this examination being accompanied by pain and tenderness radiating into the right lower extremity. The angle of the right scapula was situated a few centimetres lower than the left and a scoliosis with convexity to the left was present.

A sensory examination revealed cutaneous hyperaesthesia in the areas of distribution of the third, fourth, and fifth lumbar and first sacral roots. The lower hyperaesthetic area was found to end abruptly in the regions of distribution of the second sacral. The intensity of the knee jerk reflex was diminished and the Achilles reflex absent on the right side, while there was pain along the course of the right sciatic nerve. The antero-

FIG. 4

Case 2. Tracing of radiogram showing spondylolisthesis in a woman 28 years of age.

Note the tile-like arrangement of the third, fourth and fifth lumbar spinous processes and the indistinct outlines of the body of the fifth, which is displaced into the pelvis.

Note also the enlarged hiatus sacro-lumbalis.

posterior radiogram showed upward tilting of the fourth and fifth spinous processes, but the outlines of the body of the fifth lumbar vertebra were not visible. The forward tilting of the overlying two vertebral bodies was shown by delineation of the lower surfaces of the vertebral bodies as narrow oval shapes, especially marked in the case of the fourth lumbar vertebra. The gap between the uplifted fifth lumbar spinous process and the sacrum was enlarged and partially divided into two asymmetrical halves

FIG. 5

Case 3. Tracing of radiogram of spondylolisthesis in a man 36 years of age.

Note (a) the upward tilting of the fourth and fifth lumbar spinous processes.

(b) the asymmetry of the laminae of the fifth lumbar vertebrae.

(c) dense shadows corresponding to the position of the solution in continuity in the laminae (spondylolysis).

by the prominent spinous process of the first sacral segment. The interlaminar space between the fourth and fifth lumbar vertebrae was also asymmetrical. The visible halves of the laminae were not equal, the left being narrower, longer, and showing less curve. Shadows surrounding the pedicles admitted a suspicion of the presence of pseudarthrosis, with bony excrescences. Taking into consideration the history of the

FIG. 6

Case 7. Man 35 years of age with spondylolisthesis, showing the lordosis of the lower lumbar spine and the distinct kyphos of the dorso-lumbar junction. Notice also the furrows encircling the waist.

case, the result of clinical examination and the X-ray evidence, there was no doubt that the diagnosis of this condition was spondylolisthesis.

CASE 4. Male, aged 35. General condition good. Intensive treatment for syphilis at the age of 20; gonorrhoea in 1915. In June, 1923, while lifting a bag weighing about 80 kilos, he felt a painless cracking sensation in the lumbar region, but was able to continue his daily work. A prominence of the lumbar spine caused him to seek advice a week later.

Report on clinical examination: There is a peculiar stiff carriage of the body with marked backward inclination of the trunk, which seems slightly shortened. The inter-

costal space is one finger's depth on the right side and two on the left. The umbilicus appears to be at a lower level than usual and there is a shallow furrow in the tissues in the right lumbar region at the level of the fourth lumbar vertebra. A conspicuous kyphotic prominence of the first lumbar spinous process, painful on pressure, is present.

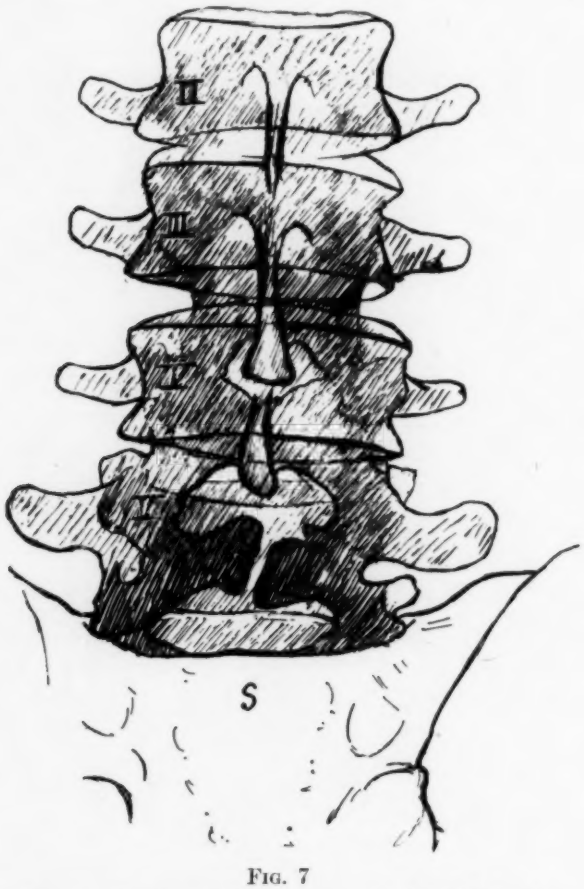

FIG. 7

Case 4. Tracing of the radiogram of the third lumbar vertebra of Case 4. Notice the spina bifida occulta in the fifth lumbar vertebra.

(Fig. 6.) From this point downward there is a lordotic curve with a hollow above the sacrum. The corresponding spinous processes seem to be displaced anteriorly, the fifth being difficult to palpate. A prominence of the body of the fifth lumbar vertebra can be felt by abdominal palpation. There is hyperaesthesia at the level of the twelfth dorsal and first lumbar and a zone of hyperaesthesia in the first sacral area of distribu-

tion. There is no increase in intensity of the normal tendon reflexes. Pain is present in the course and distribution of the right sciatic nerve. The radiogram of the case being unsuitable for reproduction, we give a schematic representation of it. (Fig. 7.) The peculiarity which arrests attention in this picture is a cleft in the spinous process of the fifth lumbar vertebra due to deficient development, while the halves of the arch are asymmetrically disposed. A deficient closure of the portion of the posterior wall of the spinal canal corresponding to the first sacral segment may also be suspected. This longitudinal defect, together with the unusual gap between the arches of the last lumbar vertebra and the sacrum, produces a mushroomlike transparent area. There is no conspicuous tilting of the overlying vertebral bodies, and a dark shadow conceals the outlines of the upper two lumbar vertebral bodies, no interval existing between them. The outlines of the last lumbar vertebral body are not as distinct as those of the fourth.

Basing our reasoning on these somewhat insufficient data, we do not venture to diagnose this case as typical spondylolisthesis, although the assumption seems reasonable that the mechanism of this derangement resembles that of the preceding cases. The visible cleft in the spinous process may have weakened the intervertebral connections, but this defect does not exclude the existence of a congenital pseudarthrosis of the laminae. The presence of a kyphosis in the upper lumbar region as a general concomitant of spondylolisthesis adds probability to this view. Our radiogram presents analogous features to the picture given by Lambl of the Padeborn pelvis, in his work on spondylolisthesis (1895). In the description of this pelvis mention is made of a cleft in the spinous process of the fifth lumbar vertebra and an elongation of the arches without loss of continuity. There is also a deficiency in the upper part of the sacral portion of the vertebral canal.

Case 5. Cavalryman, aged 36 years. Fell with horse in 1910. Paraplegic symptoms and pain in the back lasted for about a month. Severe contusions in 1915 and 1917 with gas-poisoning in addition to the latter injury. In 1920 he was thrown over his horse's head, and after a short period of rest he recovered from his acute pains, but suffered exacerbations during the following Spring and Autumn. The condition was diagnosed as sciatica and treated by electro-therapy and massage. During one severe attack of pain in July, 1922, the patient went out duck shooting and returned feeling much better. In December, 1923, while taking a fence, his horse stumbled, and in the endeavour to pull the animal up by throwing his body back he felt an acute pain in the lumbar region, but was able to continue riding till evening. The next day he felt worse and was obliged to rest in the recumbent position for a month. A diagnosis of spondylitis was made and patient wore a plaster-of-Paris jacket for four months. He was ordered a course of mud baths at Saki (Crimea) where he was accidentally met by both authors, who were enabled to make the following clinical observations: General health good; well formed body in excellent condition. There is a slight backward inclination of the trunk in the upright condition, but the lumbar lordosis is not very pronounced. With the patient in the prone position, a hollow is evident above the sacrum. Flexion of the spine is impaired and there is a painful prominence of the first lumbar spinous process. Patient has periodic attacks of pain along both sciatic nerves. A study of the radiogram submitted for our inspection reveals the usual features of spondylolisthesis. We were able to make a water colour copy of the negative (Fig. 8), which shows upward tilting of the posterior arch of the fifth lumbar vertebra with the spinous process fully developed. The lumbo-sacral space is symmetrically enlarged. There are some indistinct shadows corresponding to the interarticular portions of the

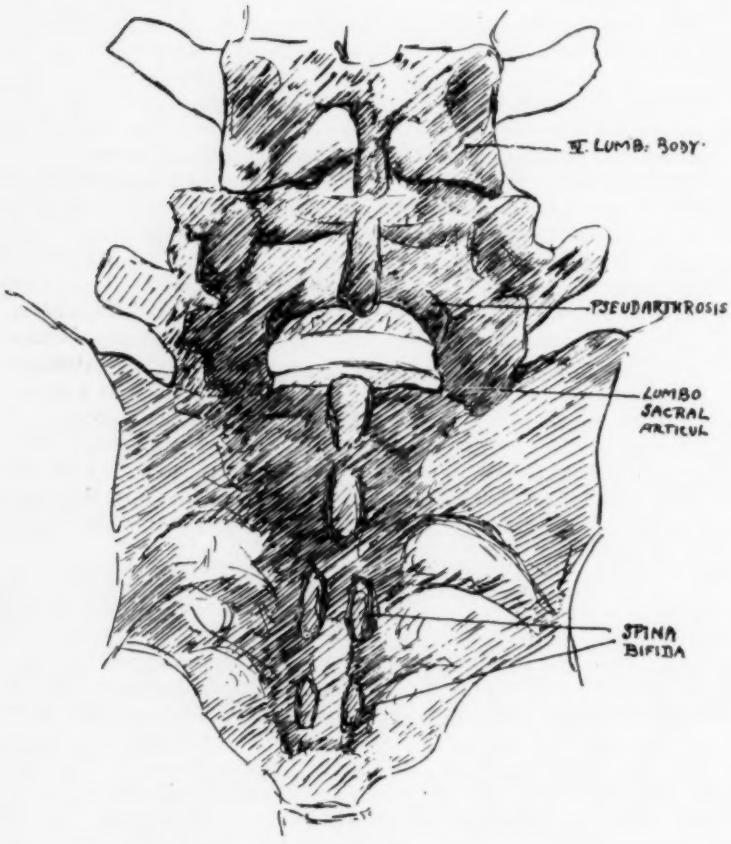

FIG. 8

Case 5. The tracing of a radiogram of spondylolisthesis in a man of 36 years.

Note (a) the upward tilting of the laminae of the fifth lumbar vertebra.

(b) enlargement of the hiatus lumbo-sacralis.

(c) increased density in the region of the pseudarthrosis of the fifth laminae (spondylolysis).

(d) the orientation of the lower surface of the body of the fourth lumbar vertebra.

(e) ossification defects of the posterior wall of the sacral canal.

fifth laminae which cause a reasonable suspicion of interruption of their continuity. The outline of the fourth vertebral body is well defined, its downward inclination being clearly shown by the outline of its base. The contour of the body of the fifth lumbar vertebra is not marked. Symmetrical shadows in the middle line of the sacrum excite suspicion of defective ossification of the posterior wall of the sacral canal (spina bifida occulta). The interpretation of the features of this case, founded on the study of the clinical course and the examination of the radiogram, may permit a positive diagnosis of spondylolisthesis being made. Using Schanz's term we may speak of "insufficiency of the fifth lumbar vertebra," but here the "insufficiency" has a definite anatomic basis, viz., a congenital defect in the formation of the walls of the spinal canal—a condition which is of frequent occurrence.

Case 6. Male, aged 36 years. Librarian. During military service in August, 1916, he fell out of an overturned cart. Ten days afterwards he began to feel pains in the loins. In December of the same year he came under our observation and a diagnosis of traumatic spondylitis was made. He was discharged after six months' treatment by recumbency and spinal corset, and subsequently had two summer courses of mud bath treatment in the Crimea. In August, 1924, he presented himself for advice, complaining of pain in the back and fatigue after walking. He then presented the typical spondylolisthetic attitude in the erect position with slight backward inclination of the trunk and impaired mobility of the spine. There was a painful small prominence of the spinous process of the first lumbar vertebra, and the hollow above the sacrum was very pronounced. A vertical line drawn upwards from the anterior superior spine crossed the clavicle about the junction of the outer and middle thirds. Abdominal palpation was rendered impossible by the degree of flatulence present and an X-ray examination of the condition was not possible.

CONCLUDING DISCUSSION

In compiling this paper founded on the existing scanty literature and our own clinical observations, we wish to focus attention on a deformity of the spine which must be acknowledged to be a definite pathologic entity and which deserves more prominence in orthopaedic investigations. The malformations of the lower end of the spine and sacrum have latterly been the subject of careful study. It has been demonstrated that this lower part of the spinal canal, being the latest to ossify, is very often the site of morphologic abnormalities and developmental failures. (Putti.)

(1) One anomaly in development may take the form of the presence of a complete or partially complete extra lumbar vertebra. (2) Defects in the ossification of the posterior wall of the spinal canal are attracting attention in the question of spina bifida occulta, the study of which condition has thrown new light on the etiology of club foot and other deformities of the lower extremity. (3) A cleft in the site of an undeveloped spinous process is a frequent finding. (4) Single or symmetrically disposed defects of ossification of the laminae (spondylolysis) also present a typical anomaly (Fig. 13) not easily detected by radiography. The affinity between this

FIG. 9

Skeletal preparation from the collection of the late Professor W. Gruber of St. Petersburg.

Personal inscription of the author on the label is as follows:

"Vert. lumb. 6, spondylolysis duplex arc. vert. lumb. 5. Non descripta."

Note the bony excrescences on the contiguous margins of the fifth lumbar and first sacral vertebrae, the result of static disturbances.

FIG. 10

Posterior view of the skeletal specimen shown in Fig. 9.

Note (a) the hiatus in the neural arch of the fifth lumbar vertebra (spondylolysis).

(b) the bony excrescences in the region of the pseudarthrosis.

FIG. 11

A skeletal preparation from the collection of the late Professor W. Gruber. Note the bony outgrowth on the left side of the junction between the fifth lumbar and first sacral bodies. This is a defensive measure of nature in response to static disturbances. The margins of the bodies of the other vertebrae also show hypertrophic changes.

last mentioned defect and other congenital developmental imperfections in the region of the lower end of the spine may be clearly demonstrated by study of a specimen belonging to the collection of the late Professor Gruber of St. Petersburg (Figs. 9 and 10). (This specimen and the one following are mentioned by Neugebauer.) The illustration shows the presence of a sixth lumbar vertebra partially sacralized. There is a break in the continuity of the interlaminar portions of the fifth lumbar vertebra. The posterior wall of the sacral canal is imperfectly developed and not strengthened by spinous processes. The posterior wall in the lower half of the sacrum beginning at the level of the third segment is absent (hiatus sacralis). Endless varieties of analogous defects in different combinations are found in Lambl's minute descriptions of the better known spondylolisthetic pelves. Taking into consideration the frequency of occurrence of spina bifida in its different degrees and varieties, it is reasonable to assume that defective ossification of the arch of the fifth lumbar vertebra must exist oftener than is suspected, either independently or in conjunction with some other congenital deficiency. The possibility of such a defect existing without any static or nervous disturbance is explained by examining carefully the changes in the corresponding skeletal area. Examination shows that special defensive measures have been taken to compensate for the abnormal weakness of the spinal column in a situation of such great functional importance. There is a broadening of the articular surfaces in the joints between the fourth and fifth and between the fifth and sixth (normally the first sacral) vertebrae. The joint surfaces have become more concave. Bony excrescences around the articular processes meet and fuse, serving for the attachment of strong ligaments for the resistance of unusual strain. The uneven rough surfaces of the corresponding arches also show traces of the attachment of strong interlaminar ligaments. The whole circumference of the pseudarthrosis seems to have been embedded in a powerful ligamentous apparatus. (The firmness of these bands may be realized when we recall another type of congenital pseudarthrosis which was formerly termed congenital fracture of the lower third of the tibia. The X-rays have aided in establishing a correct diagnosis in this condition, which ordinarily was included under the generic term of rickets.) The forward slipping and downward tilting of the body of the fifth lumbar vertebra is hindered by the strengthening of the antero-lateral ligaments, bony marginal excrescences being produced (Fig. 11). An osteophytic outgrowth thus produced is noted by Lambl under the terms "torus promontoralis sustentaculum," or "osteophytum marginale." Complete synostosis between the body of the fifth lumbar

vertebra and the sacrum is the most potent remedy against further progress of the displacement. The static derangement in the region of the upper lumbar spine caused by spondylolisthesis as previously mentioned, also produces tension on the ligaments and induces the formation of bony

FIG. 12

Drawing of the fifth lumbar vertebra from a spondylolisthetic spine, (From the collection of Professor H. Turner), shows bony excrescences at the upper border of the body, the result of static derangements in this region.

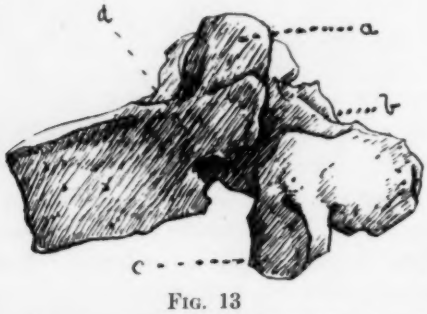

FIG. 13

Drawing of a spondylolisthetic fifth lumbar from the same specimen illustrated in Fig. 12.

Note (a) superior articular process.
(b) pseudarthrosis in the neural arch.
(c) inferior articular process.
(d) transverse process.

excrescences on the margins of the first and second lumbar vertebrae (Fig. 12). These defensive measures of nature are comparable to those already dealt with by one of us (H. T.) in discussing Pott's disease. It will be readily understood that trauma may overcome these defensive measures and interfere with their further development. The effect of

severe violence may produce grave though temporary spinal symptoms. Repeated slight injuries or physical exertion can lead to impaired static function of the vertebral column associated with pain in the back or along the course of the sciatic nerve, or with the presence of zones of hyperaesthesia. Pregnancy, imposing a gradually increasing burden on the lower part of the vertebral column, contributes to the progressive subluxation of the body of the fifth lumbar vertebra and predisposes to those forms of spondylolisthesis which are known as spondyloptosis.

In conclusion we would sum up the results of our observations as follows:

1. Spondylolisthesis is a deformity of the lower part of the spine caused by a dislocation of the body of the fifth lumbar vertebra.

2. This slipping is determined by a congenital insufficient ossification of the vertebral arch resulting in its elongation, or more generally in actual non-union of its "interarticular" portion.

3. This abnormality is one of the various forms of deficient development of the lumbo-sacral region of the spine.

4. This defect may exist without producing any pathologic signs or symptoms of functional disorder of the spine, owing to the natural accommodating defensive mechanism of the vertebral column.

5. Trauma may reveal an existing defect by the production of deformity, pain, or other clinical symptoms.

6. Injuries occurring in childhood have a more serious effect, and lead to the production of graver deformities than those occurring later in life.

7. Spondylolisthesis, or its precursor, spondylolysis, is a derangement of common occurrence met with in *both sexes* and perhaps more frequently in *males*.

8. The clinical picture and radiographic appearances of spondylolisthesis are characteristic and permit of exact diagnosis of the condition.

9. Spondylolisthesis must be ranked among the deformities of the spine occurring in every-day practice and meriting the special attention of orthopaedic surgeons.

10. Early diagnosis of the condition will serve to prevent progress of the deformity.

11. It is doubtful whether operative measures can aid conservative treatment in alleviating the symptoms and arresting the progress of the ailment.

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A NOTE ON A CAUSE OF PROTRACTED DISABILITIES IN THE REGION OF THE SHOULDER

BY JAMES T. WATKINS, M.D., SAN FRANCISCO, CALIF.

That relatively trivial injuries about the shoulder, especially when sustained by older men, may and usually do result, even after prolonged and painstaking treatment, in incomplete restitution of function is believed to be a fact generally recognized by industrial surgeons.

Now this clinical observation must have for its basis some fundamental fact or group of facts, the determination of which warrants thoughtful investigation.

The purpose of the present communication is to direct attention to at least one of these facts, noted in the study of comparative anatomy and, as a corollary to it, to emphasize what is believed to be a principle of treatment applicable to most, if not all, injuries of this group,—a principle of treatment which, while it is generally recognized, is as a rule not carried out to its logical conclusion.

When comparison is made of the anatomy of man with that of the other mammalia attention is at once attracted to the fact that no new muscles have been called into being. On the contrary, the same muscles which were adapted to plantigrade action, that is to action with the body held horizontally, have in man had orthograde functions superimposed upon them. In other words, the assumption of the erect posture has been the dominating influence in modifying the functions of the muscles of the human body; and the latter in their present state represent the selected results following upon struggles which have extended over many ages.

The anthropoid, representing an intermediate stage between the plantigrade and orthograde types, though much more nearly approximating the former, goes about with knees slightly flexed and prefers to stabilize his balance by maintaining one or both forelimbs in contact with the ground. His arboreal habitat probably explains why in the development of his shoulder girdle he so much more nearly approaches the human type than he does in the function of his lower limbs.*

*Studies of the skeletons of prehistoric man would appear to offer conclusive evidence that he, too, walked with bent knees.

It would seem then to be established that man's ability to maintain a straight knee in standing and walking, thereby dispensing with attempts at balancing by a grounded forelimb, and second, his ability to raise and maintain his arm over his head, are late acquisitions in the evolution of his muscle system, and therefore correspondingly unstable. As evidence on the clinical side of this functional instability, it has only to be recalled how when, from whatever cause, limbs have been put out of commission, these two functions are observed to be the first to retrogress and to be the last to resist efforts at restoration.

Clinically, we almost never see a damaged shoulder where the arm cannot be raised to a right angle in the saggital plane of the body. Conversely it is rare to see an old man who has sustained a shoulder injury and in whom the position of complete elevation was not maintained during convalescence, who is still able to place his arm against the side of his head.

The recognition of this characteristic of muscle function in man brings me at once to the enunciation of what must be a principle of treatment, if my premises are correct, namely: Following an injury or other damage to shoulder or knee implying prolonged immobilization, the limb should be maintained in that position which best conserves these last acquired functions. And when the upper extremity is being considered, the logical application of this principle means that the arm must be immobilized as nearly as possible at the side of the head.

And just here I must object to temporizing with this principle of treatment by means of aeroplane splints—I refer to those designed to maintain the arm at right angle elevation. They conserve the function of the muscle group which elevates the arm to the horizontal, the deltoid and supraspinatus, but to do this alone is not to take into consideration at all the action of the scapulo-thoracic group, the rhomboids, trapezius, serratus and levator anguli scapulae, whose combined effort results in raising the arm from the horizontal toward the perpendicular by producing a rotation of scapula on thorax.

That the use of the aeroplane splint represents a real advance in treatment over any method which implies the maintenance of the arm at the side is conceded. In the mass treatment of wounded men, as in the late war, its simplicity, its cheapness, its ease of construction, the speed with which it may be applied, the access which it gives to injuries, render it invaluable. But the necessities of a state of war are not the necessities of a time of peace. Nor should the industrial surgeon, with the facilities of a modern hospital at his command, and in the absence of a demand on his time and strength such as a state of war entails, be content with an

appliance which at best but half realizes a fundamental principle of treatment.

In acute cases confined to bed I have combined longitudinal elevation with some form of traction, but in ambulant cases,—and this includes those which reached me late in their convalescence,—the procedure which I have pursued with success sufficient to warrant my recording it, has been to apply a plaster-of-Paris jacket down to the trochanters, with the patient standing naturally. When the plaster had set, usually on the following day, the shoulder was manipulated, if need be under anaesthesia, and, using the excursion possible to the uninjured arm for purposes of comparison, to carry the injured arm upward to the limit of the range of normal motion and in that position to enclose it in plaster-of-Paris and unite the latter with the plaster jacket.

From this position of complete elevation, after variable lengths of time depending upon the degree of local reaction and the nature of the disability, active and cautiously conducted passive motions were carried out, care being taken in the intervals of rest to return the limb to its position of full elevation.

When this was done, it was found that in the majority of cases at the end of two weeks to two months a voluntary excursion to full elevation would be reestablished.

Indeed, I have seen one case in which, though the anterior two-thirds of the deltoid remained permanently paralyzed, the man's arm having been kept at his side for eighteen months following his injury, the patient was by this method ultimately enabled to raise his arm in the frontal plane of his body up to the side of his head—a phenomenon for which those neurologists whom I have consulted have thus far failed to give an adequate explanation.

AN OPERATION FOR THE RELIEF OF ACROMIO-CLAVICULAR LUXATIONS

BY JAMES T. WATKINS, M.D., SAN FRANCISCO, CALIF.

This fairly common disability occurs as the result of a blow or a fall on the point of the shoulder. In the resultant deformity the outer end of the clavicle is unduly prominent and at a higher level than the acromion. The disability entailed is an inability to abduct the arm through more than sixty degrees.

Occasionally the lost function is recovered in spite of the persistence of the deformity. Other cases have been recorded in which deformity was controlled until healing had taken place merely by passing an adhesive strap under the upper part of the forearm and crossing the ends over the outer end of the shoulder proximal to the joint.

It would appear to be a very general experience, however, that while the deformity is easily reduced by manipulation, it is as a rule not possible to maintain the reduction. Further, while on all sides frequent attempts have been made to relieve the disability by cutting down on the joint and seeking in various ways to suture the ends of the bones, as a rule the results have been failures and the patients have presented permanent disabilities representing serious losses of function.

My attention was first called to these facts by Doctor Gayle Moseley, Medical Director of the Aetna Life Insurance Company. At his instance I undertook a study of the shoulder to see if I could determine the manner in which the disability was brought about and some means whereby it might be relieved. Doctor Blaisdel, of the Anatomical Department of Stanford University, kindly placed the material of his department at my disposal and to him my obligation for this and many other courtesies cannot be too heartily expressed.

In this way I was enabled to observe that if traction downward were exerted upon the arm, which would simulate a thrust upon the point of the shoulder, the latter, together with the whole shoulder girdle, would descend until the clavicle came to rest upon the first rib and at the same time a forward rotation occurred about the inner end of the clavicle as a

center. This rotation explained a phenomenon, frequently verified at operation, namely that the anterior and posterior ligaments about the joint were lacerated, while the superior ones remained intact.

If now the distracting force were persisted in, either the clavicle must break or rupture must occur of the ligaments attaching the under surface of the clavicle to the coracoid process, the so-called conoid and trapezoid ligaments.

It seemed reasonable to assume, therefore, that where failure had followed suture of the structures about the joint proper, the cause must be sought in unrecognized damage to these coraco-clavicular structures. This assumption was subsequently verified when occasion was had to perform an excision of the acromio-clavicular joint for a destructive arthritis. Here it was observed that even when all the superior, anterior and posterior attachments had been removed, mutual relations of the ends of the bones remained undisturbed.

It was further observed experimentally on the cadaver that while the relations of the ends of the bones were not changed by excision of the acromio-clavicular joint proper, the instant the coraco-clavicular ligaments were severed, downward traction on the arm produced a wide separation of the two bone ends.

Finally, while operating upon a case of long standing, tissue was removed from the interval between the coracoid and clavicle and sent to the laboratory of the California University Medical School for investigation. The report came back that it was new connective tissue infiltrated with bone and cartilage cells, indicating a laceration of the limiting membrane of bone in this region.

The operation performed in this case and subsequently employed in two others was as follows. A U-shaped incision concave forward extended from the joint, which it opened freely, along the front of the clavicle and down the deltoid just internal to Mornheim's fossa. The vein was left to the inner or mesial side of the incision, and the coracoid process uncovered. This was bored through laterally at its base. Through the hole thus made was passed heavy silk—I used eighteen pound braided silk trout line doubled—which had previously been prepared by boiling for an hour in corrosive sublimate 1-1000, drying absolutely in the autoclave, and then boiling for half an hour in paraffine. The latter should be remelted and the silk removed at the moment of using it. The space between the coracoid and clavicle having been cleaned out, I bored through the latter twice, placing the posterior hole somewhat external to the anterior one. The silk was passed through these holes; the clavicle forced

downward (or the shoulder thrust upward) into place and the silk tied, using a reversed surgeon's knot. The knot was hammered flat.

The acromio-clavicular ligament was next repaired, the skin closed, and the arm immobilized in maximum elevation. I begin to bring the arm down gradually after three weeks. By the end of eight weeks the patient should be ready to undertake any ordinary occupation.

Since writing this paper my attention has been called to a paper, by F. M. Cadenat, Prosector of Anatomy in the Faculty of the University of Paris and published in Volume 1 of the 27th series of International Clinics, pages 145 to 170, dealing with the same subject.

Cadenat's experiments and clinical observations were identical with my own, as were also his conclusions. His mode of relieving the disability was materially different. He also cuts down on the coracoid, but instead of using silk to replace his coraco-clavicular ligament, he frees the acromial end of the inner fasciculus of the coraco-acromial ligament. It will be recalled that this ligament forms the vault or roof of the shoulder joint. He next carries the freed fasciculus upward from the coracoid and stitches it in succession to the remnants of the conoid, the periosteum on the posterior superior aspect of clavicle and aponeurotic attachment of trapezius. Then he also resutures the torn acromio-clavicular ligament.

Though some of my colleagues have subsequently employed with equal success the procedure outlined by myself, none of us here have thus far attempted the operation of Cadenat. For that reason comparison of the relative value of the two methods must be purely speculative. It appears from the paper just referred to that others, notably Delbet, had attempted to solve the problem in pretty much the same way I did and at an earlier date. On the other hand, Cadenat's represents a definitely original departure.

On purely theoretical grounds, one might venture to say that, other things being equal, his operation represented an anatomic triumph and mine a mechanical certainty.

THE REFORMATION OF SYNOVIAL MEMBRANE IN THE KNEES OF RABBITS AFTER SYNOVECTOMY*

BY J. ALBERT KEY, M.D., ST. LOUIS

Of recent years some surgeons interested in the treatment of infectious arthritis have in selected cases removed the thickened synovial membrane from some of the affected joints in an effort to make the joints more useful and the patients more comfortable.[1, 2, 3] In his report before the American Orthopaedic Association last year, Swett stated that out of twenty patients with chronic infectious arthritis upon whom he performed the operation of synovectomy, seventeen were definitely benefited. This being true, one naturally wonders what happens in a joint after the synovial membrane is excised. That extensive formation of scar tissue does not occur is evident from the clinical results. It is possible that the joint space persists as a cleft in the connective tissue with fibrous walls and little or no attempt by nature to cover this fibrous tissue with a cellular layer.

On the other hand, it is possible that a new synovial membrane is either regenerated from remnants left behind at the operation or reformed by a metaplasia of cells in the underlying tissues. Payr,[4] in discussing Klapp's paper in 1909, stated that he had extirpated the capsule in the large joints of a series of dogs and that there was regeneration in from two to four weeks. These experiments, however, were not reported in detail. Sumita,[5] in Payr's clinic, performed synovectomies on one knee in each of two dogs and studied the joints after twenty-three and sixty-eight days respectively. After twenty-three days the joint capsule was thicker and more cellular than normal and there was no endothelial covering. After sixty-eight days the joint resembled the control very closely. Microscopically there was a normal cellular layer upon the surface, but it was about twice as thick as that of the control and there was less fat tissue beneath the synovial membrane than on the normal side. Sumita's two dogs are, I believe, the only reported cases in the literature on the condition of joints after synovectomies. There are two reports on the repair of the defects in the joint capsule.

*From the Shriners Hospital for Crippled Children and the Department of Surgery of Washington University, St. Louis.

Wullstein,[6] in 1906, while operating upon a congenital dislocation of the patella was confronted with a large defect in the joint capsule. This he repaired by turning down a pedunculated skin flap with the epithelial surface facing the joint cavity. The result was excellent. The next year he repeated the operation upon a dog. The joint was examined after four months. It presented a smooth inner surface and microscopically the remnants of the skin flap were seen buried beneath a layer of apparently normal synovial membrane. He drew the astonishing conclusion that ectodermal skin could replace mesodermal endothelium.

Kolaczek[7] in Perthes' clinic transplanted peritoneum into defects in the capsule of one knee in five dogs. The joints were examined at intervals of from fifteen to forty-seven days. He found that the transplants persisted, but that they were covered by a layer of endothelium, which he believed grew over them from the surrounding joint surface. A certain amount of information in regard to the reformation of the synovial membrane can be gleaned from the literature on arthroplasties. Unfortunately the workers in this field have concerned themselves chiefly with what happened to the bone ends and have paid little attention to the synovial membrane. Chlumsky[8] and others who interposed various foreign bodies between the bone ends did not study the walls of the cyst-like sacs which were formed.

Murphy,[9] in his single dog experiment with an interposed flap of fascia, found a bursa-like cavity in the joint which he believed was lined by true mesothelium. Neff,[10] in one similar experiment, believed the bursa to be lined by fibrous tissue, the surface cells of which were more numerous than normal and flattened by pressure. Sumita,[5] in sixteen dogs, found similar bursae in the joint spaces. These observers believed that the bursae were formed by liquefaction in the flap.

Allison and Brooks[11] in 1913 denuded the opposing surfaces of the femur and patella and interposed silver impregnated fascia or Baer's chromicized pig's bladder between the bones. In certain instances the denuded bone became covered with a layer of fibrous tissue, the superficial cells of which resembled endothelium. Hohmeir and Magnus[12] performed arthroplasties on sixteen rabbits. In seven, muscle flaps were interposed and in nine the bone ends were simply resected and the capsule sutured. In both series the bones became covered by a fibrous layer, the inner surface of which was covered by endothelium. Phemister and Miller[13] performed a larger series of similar experiments on dogs and obtained similar results with or without the interposition of soft parts. They noted in certain instances a fairly good endothelial lining, especially along the

surface of the adhesions and surfaces free from pressure. Baer[14] opened four human joints after the insertion of chromicized pig's bladder. The cavities were smooth and the walls consisted of fibrous tissue infiltrated with round cells. Towards the surface the cells were flattened, but no endothelial lining was present.

With the exception of Sumita none of the workers in experimental Irthroplasty excised the synovial membrane at the time of the operation. at is thus evident that the endothelial-like coverings noted by the above observers may have been simply extensions of the normal lining of the joint. There is then some evidence that synovial membrane tends to regenerate after excision, but very little is known of the process by which the new lining of the joint cavity is formed. I have studied the knee joints of a series of rabbits at various intervals after partial synovectomy and the results are recorded below.

MATERIAL AND METHODS

Under ether anaesthesia the hair over the knee was removed with barium sulphide solution and the skin cleaned with alcohol. A slightly curved incision was made through the skin and superficial fascia on the outer side of the extremity opposite the knee. The loose skin was then drawn inwards across the patella and the capsule of the knee incised down to the synovia on the inner side. The incision in the capsule extended from the tibia up into the vastus externus muscle to a level opposite the upper end of the quadriceps pouch. The synovial membrane was then dissected up from the side of the femur and from the capsule of the entire mesial half of the joint and quadriceps pouch. Having been raised from the underlying tissue before the joint cavity was opened, the synovial membrane of the mesial side of the joint was cut away from the border of the femur below and from the patella and quadriceps tendon above and removed in one piece. The infrapatellar fat pad was removed and in most cases the anterior half of the internal semilunar cartilage was removed. In some instances the cartilage was cut across and left in place. The ligaments and posterior joint space were left intact. The capsule was then sutured with fine silk and the skin pulled back and sutured with coarse silk, and a collodion dressing applied. In all, thirty-five rabbits were operated upon, but in eleven the knees became infected so that only twenty-four joints were studied. At two, three, four, five, six, eight, ten, twelve, thirteen, fifteen, sixteen, seventeen, twenty, twenty-two, twenty-eight, thirty-two, thirty-five, forty-six, fifty-four, sixty, eighty-six, and one hundred and four days after operation the rabbits were given lethal

ether and the knee excised. The joint fluid was studied and the knee was then opened and inspected and fixed in Zenker's fluid. A section of the capsule was excised for immediate embedding and then the joints were decalcified in 5 per cent. nitric acid and embedded in paraffin or celloidin. Sections were stained in haematoxylin and eosin, phosphotungstic acid haematoxylin, aniline blue acid fuchsin, and by Van Geison's method.

RESULTS

In the twenty-four instances in which the knee did not become infected the animals began to use the extremity after a few days, and by the time the skin wound was healed the swelling had disappeared and function was apparently normal. In no case was there any limitation of motion or limp.

MACROSCOPIC APPEARANCE OF THE JOINTS

Forty-eight hours after hemisynovectomy the knee was distended with bloody fluid. The sutures were on the surface of the membrane, and the denuded area was sharply defined. This surface was, however, glistening and more smooth than the raw surface left at operation. The mesial pouch and site of the infrapatellar fat pad were occupied by greyish red adherent clots of blood and fibrin. On the third, fourth and sixth days the amount of blood was progressively lessened and the denuded area became more smooth and translucent. By the fifth day the sutures were covered by a glistening translucent layer and the clots in the mesial pouch and anterior space had diminished in size. From the sixth to the fifteenth day the excess fluid gradually disappeared from the joint, and the boundaries between the denuded area and the original synovial lining became less distinct. During this period the denuded area was uniformly covered by a rather thick, soft, pink layer of tissue which was more smooth than the granulation tissue of an open wound. The sutures after the twelfth day were no longer visible beneath the surface. The clot in the anterior joint space was gradually replaced by a mass of tissue similar to that covering the denuded area. There was constantly present an adhesion of this tissue to the inter-condylar notch of the femur. During this stage the mesial pouch was shallower than on the unoperated side and its bottom was irregular and crossed by delicate folds and a band of tissue. From the fifteenth day on, the surface of the denuded area became more pale and firmer in texture and gradually approached in appearance the surface of the unoperated side. By the end of the third week the two halves of the joint resembled one another very closely. The mesial pouch was deepened

and the delicate adhesions disappeared. The fat pad maintained its attachment to the intercondylar space and enlarged to fill this space.

In instances where the internal semilunar cartilage was simply cut across and left *in situ* its ends remained free for a considerable time, but by the end of the fourth week were united by a translucent scar. The union apparently began at the base of the cartilage and grew outward towards its edge. In instances where the anterior half of the cartilage was removed there was no tendency for the cartilage to regenerate, but the regenerating fat pad extended mesially over the tibia to become attached to the free end of the cartilage. In the longest experiments, eighty-six and one hundred and four days, the fat pad was still slightly smaller and more vascular than normal, but the synovial membrane was apparently uniform throughout the joint. In every instance the changes in the denuded surface were uniform over the whole area. There was no evidence of any surface growth from the edges to cover the denuded areas as occurs in the repair of a defect in an epithelial surface.

MICROSCOPIC CHANGES

The joint fluid was studied by the vital method in every experiment, but the changes will not be dealt with in detail here. Suffice it to state that forty-eight hours after synovectomy the fluid was very cellular and the cells were largely red blood cells and polymorphonuclear leucocytes. At this stage about twenty per cent. of the nucleated cells were clasmatocytes and monocytes. These were actively phagocytizing the red cells and leucocytes. By the sixth day the red cells and polymorphonuclear leucocytes had largely disappeared and the clasmatocytes had been largely replaced by monocytes (a slightly different type of wandering phagocytic cell). As time went on the monocytes dominated the picture, though a few clasmatocytes were constantly present, and the cellular content gradually diminished to that of normal synovial fluid (100-300 per cu. mm.). At no time was there any tendency to extensive desquamation of the lining cells. An occasional lining cell may be met with at any stage but they never exceeded 10 per cent. of the phagocytic wandering cells.

THE DENUDED JOINT SURFACE

A section of a joint forty-eight hours after hemisynovectomy showed the joint space partly filled with exudate. The coagulated exudate was adherent to the denuded surface. Beneath this layer of fibrin and blood and wandering connective tissue cells the fixed connective cells were increased in number and in size. They had the vesicular nucleus and the

pale blue cytoplasm of fibroblasts. Mitotic figures were abundant and the fibroblasts were present in the deeper layers of the adherent fibrin. This proliferation of fibroblasts was present throughout the denuded area whether the subsynovial tissue were periosteum, fibrous joint capsule, or striated muscle. The subsynovial tissue was moderately infiltrated with

FIG. 1

Joint space two days after synovectomy. Side of the femur on the left. Vastus internus on right. The denuded surface is infiltrated with extravasated blood and phagocytic cells. 16 mm. objective.

polymorphonuclear leucocytes and phagocytic mononuclear cells and contained much extravasated blood. A few delicate newly formed capillaries were present (Fig. 1).

In a joint four days after hemisynovectomy the joint space was relatively clear and the fibrin adherent to the denuded area had a smooth surface which was sharply demarcated by a thin hyaline-like surface

layer which stained blue with Mallory's aniline blue while the fibrin stained pink with the acid fuchsin. The fibroblasts had increased greatly in number and had wandered out into the fibrin layers. They were cylindrical and stellate in shape and lay mostly with their long axes perpendicular to

FIG. 2

Six days after synovectomy. Mesial wall of joint near bottom of the pouch. The blood clot is infiltrated with fibroblasts and young blood vessels. 8 mm. objective.

the joint surface. They apparently arose from the subsynovial tissue and wandered into the adherent fibrin. Polymorphonuclear leucocytes and phagocytic mononuclears lay on the surface, in the hyaline layer, in the fibrin layer, and scattered through the subsynovial tissues. The fibroblasts did not penetrate the hyaline surface layer, but some of them lay just beneath it with their long axes parallel with the surface. A

moderate number of delicate capillaries extended from the subsynovial tissue into the layer of fibrin and were growing directly towards the joint surface. The fibrin coating was being organized rapidly.

FIG. 3

Six days after synovectomy. Surface of new membrane. The fibroblasts lie in a mass of blood cells and fibrin. One mitotic figure in the field. 2 mm. oil immersion objective.

Six days after operation the denuded surface was covered by a loose layer of fibroblasts .3 to 1.5 mm. in thickness (Fig. 2). No collagenic fibres were present, but the fibroblasts and capillaries lay in a fibrin matrix. Some of the fibroblasts lay directly on the surface and others sent their

processes to the surface (Fig. 3). These protoplasmic processes might project into the joint cavity, but usually lay along the surface. Beneath the surface great numbers of these protoplasmic processes were cut trans-

FIG. 4

Ten days after synovectomy. Side of femur. New membrane rather thin in this area. 8 mm. objective.

versely in the section and appeared as small pale blue masses. The sutures were covered by the layer of fibroblasts. At the eighth day the fibroblasts were still more numerous and lay with their long axes parallel with the surface. Ten days after operation the denuded area was covered by a thick, highly cellular layer, with abundant capillaries. At this stage the

extravasated blood and phagocytic cells had largely disappeared and only a small amount of fibrin was present beneath the surface. A few delicate collagenic fibres appeared in the newly formed tissue and a surface zone of more closely packed fibroblasts was fairly well defined (Fig. 4). The

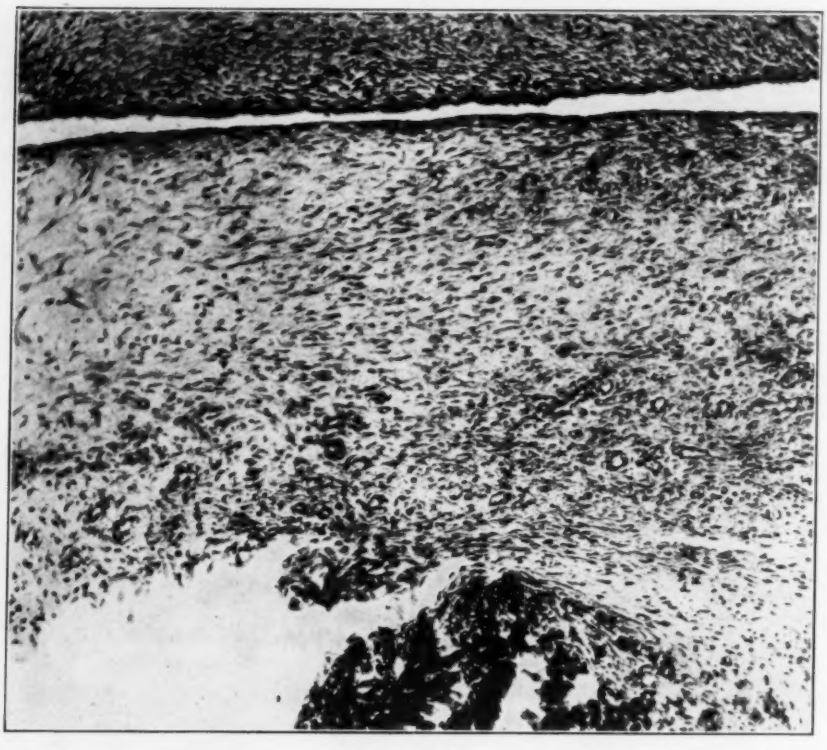

FIG. 5

Thirteen days after synovectomy. Joint space with suture line at bottom of picture. The new tissue covers the suture without interruption. 8 mm. objective.

hyaline surface zone had disappeared from much of the surface, but was present in the bottom of the lateral pouch until the fifteenth day or later.

From the tenth to the sixteenth day after operation the proliferation of the fibroblasts continued and the newly formed membrane became more cellular (Fig. 5). But the predominant change during this period was the laying down of collagenic fibres between the fibroblasts. In the ten-day experiment only a few delicate fibrillae were demonstrable in the depths of the new membrane. By the sixteenth day a connective tissue stain

demonstrated great numbers of delicate wavy collagenic fibres throughout the newly formed tissue. For the most part they lay parallel with the surface, but a few cross fibres were also present. It is to be noted that these collagenic fibres are laid down after the fibrin has largely disappeared. This suggests that these fibres are not condensation products of the

FIG. 6

Twenty-two days after synovectomy. Surface of new membrane with cells more numerous along the surface. 4 mm. objective.

fibrin, but are formed by the gradually maturing fibroblasts. After the sixteenth day not only were no mitotic figures seen, but the cells definitely decreased in number and the new membrane decreased in thickness. At twenty-two days the synovial membrane was markedly thickened in the bottom of the mesial fold, but on the side of the femur, near the cartilage, it was little thicker than normal (Fig. 6). The connective tissue cells were

generally small with dark nuclei as in the resting adult stage. There was a well defined surface layer of one to four cells in thickness. These cells were obviously connective tissue cells and were more numerous and closer to one another than are the surface cells of normal synovial membrane.

FIG. 7

Thirty-two days after synovectomy. A small villus. 4 mm. objective.

Some of these cells lay directly upon the surface, but the majority of them lay beneath the surface, being either completely covered by a delicate collagenic layer or being partly covered by this and having one or more of the protoplasmic processes free on the surface. Beneath the surface the rather loose fibrous layer was abundantly supplied with blood vessels.

In places a thin layer of loose areolar tissue lay between the cellular layer and the fibrous tissue layer.

After the fourth week the evolution of the new joint lining was more gradual and the changes were not uniform throughout the joint. The changes which occurred were a decrease in number and size of the connec-

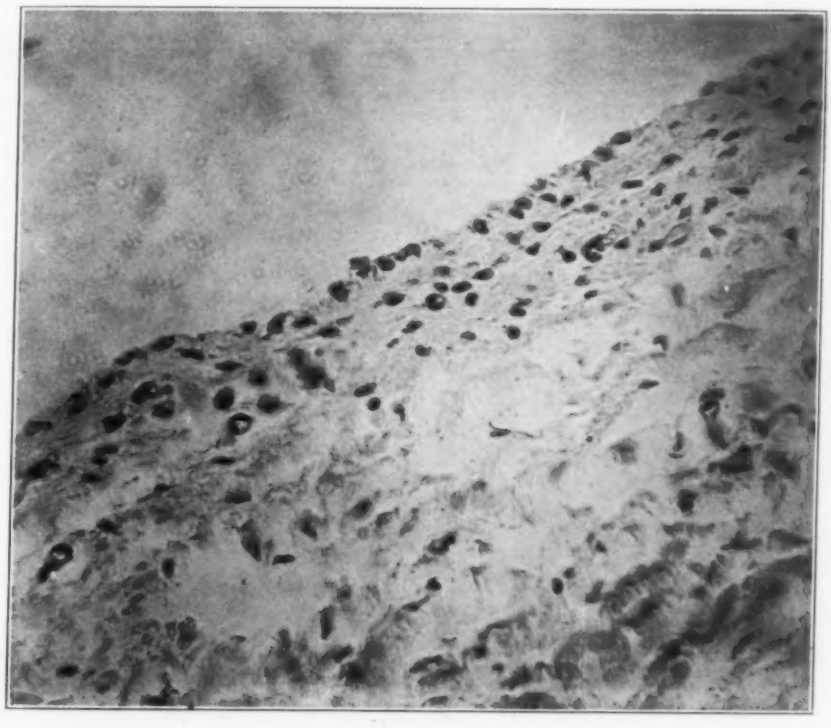

FIG. 8

One hundred and four days after synovectomy. Surface of the new membrane. 4 mm. objective.

tive tissue cells, both on the surface and in the membrane, a condensation of the loose fibrous tissue into bands, and a decrease in the number of blood vessels.

The zone of surface cells, which may be termed synovial cells as they now form a well defined layer, even at thirty-five days may in small areas consist of a single layer of flattened cells similar to that in the normal joint. On the other hand, the average surface layer at this period is about

three to four cells in thickness (Fig. 7). At sixty days the average was about that of the normal joint, but there were isolated areas where six to eight layers of cells were heaped up. In these spots the cells were larger,

FIG. 9

Eighteen days after synovectomy. Fringe along side of quadriceps tendon in an infected joint. 8 mm. objective.

less flattened, and more deeply stained than are the usual synovial cells. At eighty and one hundred and four days the picture was little changed. The cells were perhaps a little more flattened and more widely separated on the surface in the older cases (Fig. 8).

Just beneath the surface layer was a narrow zone of rather loose areolar tissue which at thirty-five days was richly supplied with small vessels. At sixty days these vessels had decreased in number until they were about the same as those of the normal joint. These vessels may lie very close to the surface, being covered only by a single flattened cell layer or by a very thin collagenic layer. It is to be noted that this areolar

FIG. 10

Thirty-five days after synovectomy. Fibrocartilage of quadriceps tendon on the right and new membrane on the left. The irregularity of the surface is due to the mild infection present in this joint. 8 mm. objective.

layer may fail entirely, as it does in many parts of the normal joint, and the surface cells lie directly upon the rather dense fibrous layer.

The fibrous layer at sixty days reached its permanent condition. It does not form a uniform layer as in the normal joint, but as the cells decrease in size and number and the collagenic fibres increase in size, the fibres tend to collect in irregular bundles. These bundles in the main lie parallel with the surface, but their variable size and direction causes the

surface to be more uneven than normal. Occasionally a dense band of fibrous tissue will cross the joint cavity as an adhesion between the lateral wall and the side of the femur. More frequently the band merely projects into the cavity as a fold in the surface. These adhesions and folds are covered by lining cells, but the areolar layer as a rule is not present.

Villi are larger and more numerous in the synovectomized area. They have a central core of collagenic fibrous tissue and usually contain one or more blood vessels. The tip is usually more cellular than the adjacent synovial surface, but the sides of the villi are sparsely cellular. Occasionally small villi are simply projections of collagenic tissue, containing no vessels or cells. At the cartilaginous border of the femur and especially of the patella, large villi very frequently are found projecting over the cartilage. This is especially true in the mildly infected joints where long fringe-like folds may be present (Fig. 9). In other instances of mild infection the long villi are absent, but the membrane is unusually vascular and much more cellular than is that of a non-infected joint. Such a thickened membrane was moderately infiltrated with polymorphonuclear leucocytes and on the section the surface was irregular (Fig. 10). In this figure the fibrocartilage of the quadriceps tendon showed evidence of regeneration at its cut margin, but no infiltration with leucocytes.

In the formation of the new synovial membrane the bottom of the mesial space, where the synovia covering the femur is reflected up onto the fibrous capsule, lags behind the remainder of the denuded surface. This area may contain fibrin up to twenty-two days and its surface zone is not well defined even at thirty-two days. Apparently this area is subject to frequent trauma by joint motion, and the tendency of the fibroblasts is to obliterate the joint cavity by pushing forward and bridging the space between the femur and the mesial capsule. Adhesions are most frequent in this area. It is noticeable that these adhesions are much more numerous in the early stages. Apparently they are broken down and the joint cavity enlarged to its original dimensions by frequent motion.

A second area that is even slower to be restored than the above is that of the infrapatellar fat pad or alar ligaments. At the operation this tissue was excised down to the patellar tendon. As was stated, after the operation this region is nearly filled by a fibrous clot which is adherent to the intercondylar surface of the femur as is the normal fat pad. This clot is quickly invaded by a few fibroblasts and phagocytic wandering cells and is later vascularized. The clot shrinks in size and is soon covered by a surface layer of lining cells or fibroblasts. Later fat is deposited and the fat pad is reformed. Even at one hundred and four days, however, it has

not reached its original size and its surface cells are larger and more numerous than normal. The surface is also very irregular, being a continuous series of depressions and elevations with frequent branching processes. The substance of the new fat pad is denser and contains more collagenic tissue than normal (Fig. 11).

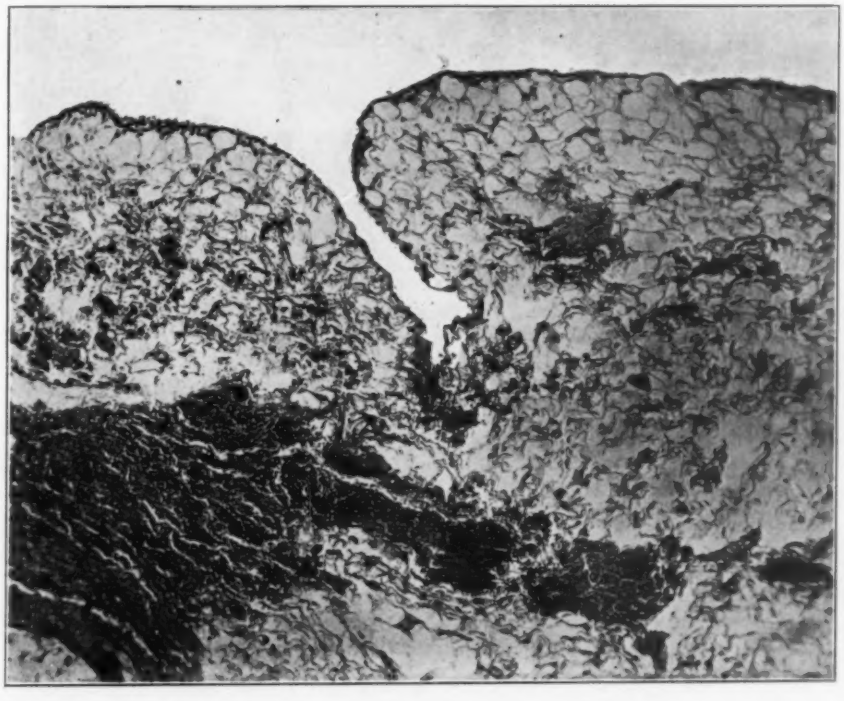

FIG. 11

Fifty-six days after synovectomy. Regenerating infrapatellar fat pad showing fibrosis. 16 mm. objective.

In about a fourth of the operated joints one or more osteo-cartilaginous processes were formed on the femur. This occurred in spite of the fact tnat at the operation care was taken not to injure the periosteum more than necessary. These exostoses were not formed as spurs at the cartilaginous margin, but were usually well down on the side of the condyle. The earliest one was seen in the section of the four-day joint. It was simply a proliferation of the deeply staining osteoblasts between the cortex of the bone and fibrous periosteum. In one five-day joint a definite cartilag-

inous process was present beneath the periosteum. In three joints between twenty and thirty-two days after operation very large exostoses were present on the postero-mesial aspect of the internal condyle. In these instances the exostoses were about as thick as the condyle itself. Two of these large exostoses occurred in mildly infected joints and one in a

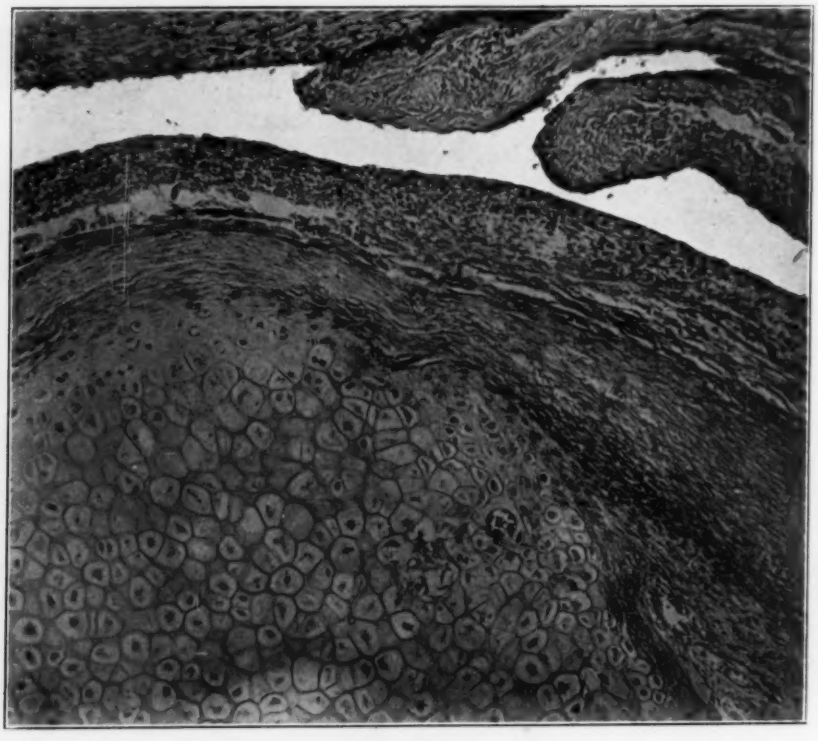

FIG. 12

Sixteen days after synovectomy. Joint space with two large villi projecting from the bottom of the mesial pouch. A cartilaginous exostosis growing from the side of the mesial condyle of the femur. 16 mm. objective.

clean joint. They were partly calcified and as a rule the ossification occurred in cartilage, but in some instances the new bone seemed to be formed directly by the osteoblasts. They were always covered by a fibrous layer of periosteum (Fig. 12).

In the unoperated side of the joint the synovial cells increased in size and slightly in number, but returned to the normal state by about the fifteenth day.

SUMMARY AND CONCLUSIONS

After the removal of the synovial membrane the joint is filled with a mixture of blood and synovial fluid. A clot of cells and fibrin adheres to the denuded surface. There is an immediate polymorphonuclear leucocyte reaction which lasts about forty-eight hours, and then the polymorphs disappear and phagocytes (clasmatocytes and monocytes) wander into the joint. The fixed connective cells of the denuded area enlarge, proliferate rapidly, and invade the adherent fibrin. Capillaries grow into the fibrin, and by the sixth day it is fairly well organized. By the fourth day a definite surface zone on the adherent fibrin is demarcated by a thin hyaline layer which stains as does collagenic tissue. This surface zone for a time is not penetrated by the advancing fibroblasts, but they form a layer just beneath it.

As the clot becomes organized the fibrin and extravasated blood are absorbed and by the tenth day a few collagenic fibres are present. These are rapidly increased during the next five days. Mitotic figures are frequent and the proliferation of fibroblasts continues until about the fifteenth day. At this time the fibrin has almost entirely disappeared and the hyaline surface layer has largely disappeared. The denuded area is now covered by a thick, highly cellular layer of loose fibrous tissue which is very vascular and has a well defined surface layer of fibroblasts.

This membrane of young connective tissue now slowly matures to form a synovial lining which can be distinguished only with difficulty from that of the normal joint. The fibroblasts beneath the surface decrease markedly in number and those remaining shrink in size to become normal lamellar cells of connective tissue. As the fibroblasts decrease in size and number collagenic fibres are laid down. The surface or synovial cells are decreased in size and number and become flattened. They lie not on the surface but in the surface, as is true of normal synovial membrane. Joints are not lined by a layer of mesothelium but their lining is a connective tissue surface made up of cells and collagenic tissue. The cells may be likened to field stones. Some are on the surface, some are partly buried, and others are wholly covered by the collagenic matrix.

The joint space up to fifteen days encroaches upon the newly formed membrane. After that time, partly from condensation of the membrane and partly by stretching and breaking down of adhesions, it becomes approximately normal in size and contour. The resultant membrane has a more irregular fibrous ground work than has the normal synovia and, as was noted by Sumita,[5] is deficient in the subsynovial areolar tissue.

In this series, exostoses on the mesial condyle were frequent. These

are believed to be due to inadvertent injury to the periosteum at the time of the operation.

In the rabbit the joint is again approximately normal sixty days after hemisynovectomy. The new synovial membrane is formed *in situ* by metaplasia of underlying connective tissue cells and there is little or no tendency for surface growth from the edges to cover the denuded area as occurs in the repair of a defect in an epithelial surface. The synovial cells are connective tissue cells slightly specialized by their location on a free connective tissue surface.

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DISCUSSION

Dr. Paul P. Swett, Hartford, Conn.: It is very gratifying to have this splendid piece of research come before this meeting. Dr. Key is to be congratulated. The anatomy of the synovial membrane is of prime importance to orthopaedic surgeons. Dr. Key's careful studies of the process of repair enable us to visualize what occurs in the synovial membrane after synovectomy. In two cases which came under my observation several months after synovectomy I found a replacement of synovial

membrane with no evidence of scar tissue. These beautiful experiments of Dr. Key show that we are justified in expecting a process of repair which, in itself, will not disturb the functional integrity of the joint.

Dr. P. W. Nathan, New York City: I would like to ask a question. The work has been so well done and so beautifully presented that discussion is unnecessary, but, as Dr. Key no doubt knows, there are often cartilage cells found in the synovial membrane. I would like to ask the Doctor whether he has found any cartilage cells in this synovial membrane.

Dr. J. Albert Key, Boston (closing the discussion): In answer to Dr. Nathan's question, I have not seen cartilage formed in the denuded area except as produced by a definite growth from the bone.

VERTEBRAL EPIPHYSITIS. A CAUSE OF SPINAL DEFORMITY.*

BY JOSEPH BUCHMAN, B.S., M.D., BROOKLYN, N. Y.

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My attention was recently drawn to an article by André Delahaye[1] describing an entity which he terms *l'épiphysite vertébrale de croissance.* The syndrome as he describes it appears between the ages of ten and twenty-one. Its onset may or may not be accompanied by a slight rise in fever. There is pain and tenderness over the spinous processes, the bodies of the lumbar vertebrae, and the iliac crests. This is associated with spasm in the muscles of the back and limitation of motion in all directions. He presents three cases, in all of which the superior and inferior epiphyseal areas of ossification of the vertebral bodies show anomalies of location, form, and tenderness. These cases did not have gross deformities of the spine. He also reports a painful kyphosis of adolescence, with tenderness at the level of the seventh dorsal spine, muscle spasm, and a roentgenogram which showed flattened, laminated, clearly defined epiphyseal centers, and cuneiform shaped vertebrae. He concludes that this condition may explain many deformities acquired in adolescence resulting in kyphosis and scoliosis.

As I had chanced to see several cases with the same symptoms and X-ray findings as those described by Dr. Delahaye, I undertook at the Hospital for the Ruptured and the Crippled, while on the service of Dr. Royal Whitman, to investigate the relationship existing between the abnormal changes in the superior and inferior vertebral epiphyses and the acquired deformities of adolescence. There is much diversity of opinion among authorities on the subject of ossification of the vertebral column. Consequently I made a study of the normal spine, limiting myself to a consideration of the superior and inferior vertebral body epiphyses, their normal appearance, and the age at which they may first be seen.

Poirier[2] states that the superior and inferior vertebral epiphyses

*Presented at the Annual Meeting of the American Orthopaedic Association, Washington, D.C., May, 1925.

FIG. 1

Spine of 16-year-old boy showing normal epiphyses. (a) Central portion or diaphysis; (b) upper epiphyseal cartilage; (c) lower epiphyseal cartilage; (d) superior bony epiphysis; (e) inferior bony epiphysis; (f) intervertebral space.

appear between eighteen and twenty years of age. Sabotta and McMurrich[3] and Cunningham[4] place the time of appearance at puberty or later; Piersol,[5] at seventeen years of age; Gray,[6] at sixteen years of age; Baetjer and Waters,[7] at twenty-one years of age; Scheuermann,[8] at fourteen to fifteen; Koehler, at eleven; and Delahaye,[1] at twelve years. In my series of normal spines, the superior and inferior epiphyses were first seen at eleven and one-half years of age. They appear first in the lower dorsal region and then extend up and down the column as small triangular shadows adjacent to the anterior inferior and the anterior superior angles of the bodies. Later they become elongated and appear as thickenings placed anteriorly and thin linear shadows extending backwards and terminating at the posterior angles of the bodies of the vertebrae, where they become thickened. When seen in perspective these epiphyses appear as rings, which are described as thick peripherally and thin centrally. Each vertebral body, therefore, consists, at the age of eleven and one-half and over, of a central portion, the diaphysis, and an upper and lower epiphyseal cartilage, and beyond that an upper and lower bony epiphysis (Fig. 1).

Normally the intervertebral spaces are clear and should present the same degree of clarity in the whole extent of the spine. Sometimes one sees exceptions to this in the antero-posterior view of the lower dorsal region in that the spaces in this area are hazy. The haziness is, however, uniform in density and there is no mottling. The vertebral outlines are regular and distinct. The same haziness is seen in a lateral view of the upper lumbar region. The superior and inferior epiphyseal plaques are at all times difficult to see in the antero-posterior view because of the superimposition of the shadows of the articulating masses and the spinous processes. Laterally, however, the plaques are distinctly seen at about twelve years of age (Fig. 1).

I have examined one hundred and twenty unselected cases of various spine affections. Out of sixty-five of so-called idiopathic posterior curvature and lateral curvature, fifty-four or 83 per cent. showed positive evidence of the type of epiphyseal disease I shall describe. Three cases without any clinical spinal deformities showed a similar involvement. Of the latter three, two were symptomless. I mention these three cases as definite proof that the epiphyseal involvement to be described is primary and not secondary to the deformity, as has been elsewhere suggested. The remaining fifty-two cases were all negative and these included a variety of conditions in which the etiology is definite, namely: nineteen cases of spinal deformities due to poliomyelitis, six cases of osteoarthritis of the

FIG. 2

Spine of 13-year-old girl clinically normal, showing (a) mottling and haziness of the upper dorsal intervertebral spaces, (b) indistinct and irregular upper and lower vertebral borders, and (c) thickened epiphyses. This is an early case.

spine, three cases of congenital deformities, three cases of rickets, one case of polyarthritis, four cases of trauma, eleven cases of Pott's disease, four cases secondary to sacro-iliac conditions, and one case following pyothorax.

FIG. 3

Spine of a 15-year-old boy clinically normal, showing early changes: (a) enlarged, frayed, and irregular epiphyses; (b) intervertebral spaces are mottled and hazy.

The pathologic changes noted in the positive cases varied according to the stage of the involvement. In the earliest stages the vertebral epiphyseal plaques are rarified, enlarged, and their outlines are frayed and moth-eaten. The intervertebral spaces are irregularly cloudy and mottled

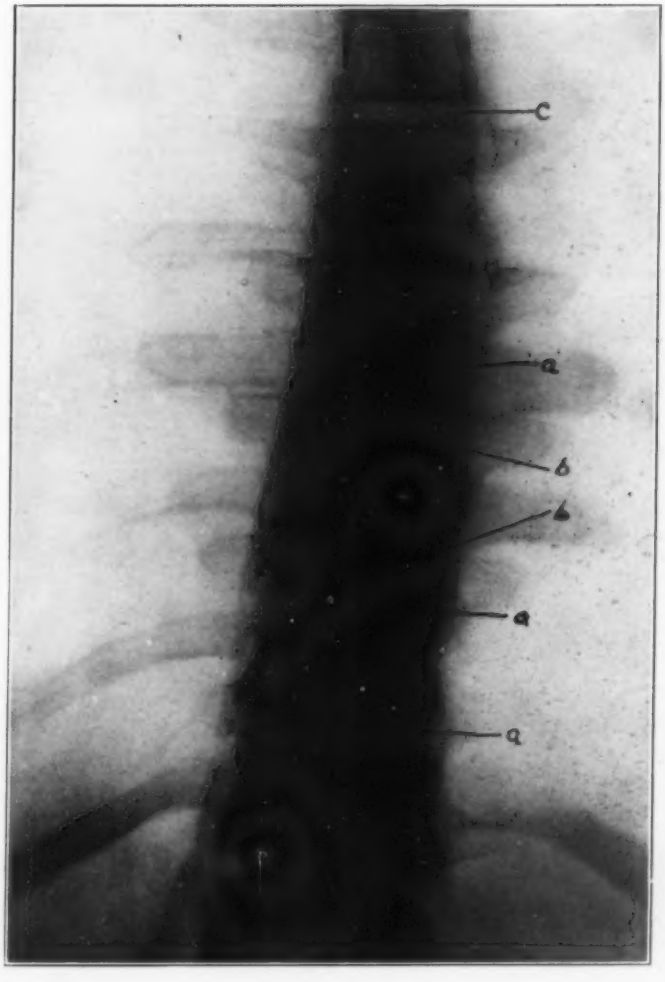

FIG. 4

Spine of a 15-year-old girl with round shoulders, hollow back, and backache. This, like the cases in Figs. 2 and 3, is an early case. (a) The intervertebral spaces are fogged, mottled, and diminished in breadth and the vertebral outlines are indistinct; (b) apparently fused vertebrae; (c) normal intervertebral spaces.

FIG. 5

Lateral view of spine shown in Fig. 4. (a) The outlines of the lower dorsal bodies are irregular, frayed, and moth eaten; (b) the intervertebral spaces are mottled, hazy, irregular, and diminished in breadth; (c) the bodies are wedged.

FIG. 6

Spine of a 15-year-old boy with a rigid posterior dorsal curvature, showing wedging of vertebral bodies and thickened, sclerosed, and irregular outline of bodies.

while the adjacent vertebral borders are indistinct and irregular. Finally the stage is reached when the spaces may be differentiated from the bodies with difficulty or not at all, and sections of the spine, especially in the lateral view, appear as one continuous fused mass. When the stage of regression sets in, the parts become more and more differentiated, and there is an appearance of fragmentation and striation in the spaces. The vertebral outlines become more distinct, but are definitely irregular and at times moth-eaten. The epiphyses may now become differentiated and they appear as dense shadows, but they do not return to their normal size. The vertebral borders are seen as dense shadows as if they were sclerosed. At this stage, more so than in the former, the vertebral bodies may be wedge shaped. In the final adult form the superior and inferior borders have an irregular, dense, striated appearance (Figs. 2 to 12).

Clinically, this condition seems to be a self-limited affection involving the epiphyses of the spine, most commonly in the dorsal region. Other epiphyses, such as those of the iliac crests or other parts of the body, may be involved concomitantly. The condition occurs between ten and twenty-one years of age. The onset is usually associated with a sensation of fatigue and backache and pains in the limbs. There is tenderness over the spinous processes, especially in the dorsal region. The lumbar bodies are occasionally tender on abdominal palpation. The epiphyses of the iliac crests and those of the extremities may also be painful to pressure. When first noted the roentgenologic pathology is usually well developed, though in one of our series the X-ray findings were slight. Deformity develops secondarily and it may be a kyphosis or a scoliosis. Frequently the condition is entirely asymptomatic or the symptoms may be so slight that they attract little or no attention. The deformity is the disturbing factor and it is because of the deformity that the doctor's aid is sought. The patients are usually well developed and well nourished children.

CASE HISTORIES

Olga M., 13 years of age, gave a history of four or five attacks of tonsillitis. Nine months ago she noticed that she became easily tired, had little inclination to play, and that she had pain in the back on excessive exertion. Three months later her mother noticed that her back was crooked. She also gave a history of pain in the right foot. Physical examination showed that she was a fairly tall, rather slender girl, whose posture was poor. Her back was asymmetrical and the spine presented a slight posterior curve as well as a left dorsal lateral curvature. There was tenderness over the spinous and transverse processes from the seventh cervical vertebra down to the sacrum. The anterior third of the iliac crests, the tarsal scaphoids, both fore-feet, both tibial tubercles, the tibial tuberosities, the femoral condyles, the humeral condyles, the shoulders, the lumbar bodies as shown by deep abdominal palpation, and the sides of the neck were all

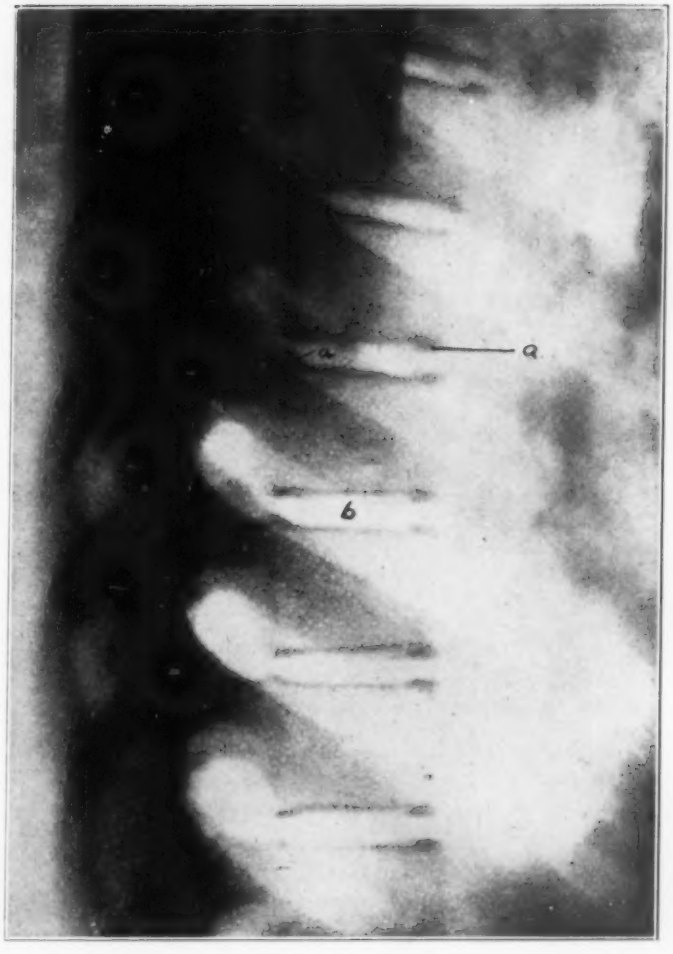

FIG. 7

Spine of Ray F. (See Case Histories.) This is a late stage of period of regression. The epiphyses (a) are enlarged and thickened. The intervertebral spaces (b) are clear.

tender. Roentgenograms showed a typical picture of epiphyseal involvement. One might possibly conclude from the history that the tonsillitis brought on a systemic infection which localized in the epiphyses with a consequent derangement of the vertebral epiphyses and a deformity of the spine.

Jennie L., 13 years old, complained of backache. Examination showed that she had a moderate degree of kyphosis. There was tenderness of the spinous processes of the lower cervical and upper dorsal vertebrae and of both iliac crests. Roentgenograms revealed typical pictures of epiphyseal disease.

Ray F., 16 years of age, stated that she had round shoulders for the past six years. She entered the hospital because of pain and discomfort. The pain was referred to the dorsal region of the spine and was induced by sitting and by exertion. Examination revealed a long posterior curve of the spine and a slight rotation to the left in the lower dorsal region. Roentgenogram showed the characteristic picture of epiphyseal disease in its late stages; that is, much enlarged epiphyses. (Fig. 7.)

Florence H., 17 years of age, complained of a curvature of the spine discovered three years ago. There was no history of pain. She had had discomfort and a continuous sensation of fatigue for the past year. Examination showed a moderate mid-dorsal kypho-scoliosis. The roentgenograms are typical of vertebral epiphysitis.

Paul H., 14 years of age, complained of deformity of the back and pain in the lumbo-sacral region noted four weeks previously, when he was hurt while playing basket ball. Pain increased with activity. His past history was negative save for sore throats. Examination showed a right dorsal, left lumbar scoliosis with a slight degree of round shoulders. The muscles of the back were in spasm and the motions of the spine were limited in all directions. There was marked tenderness over the spine of the third lumbar vertebra and over the crest of the right iliac bone. The roentgenograms showed characteristic epiphyseal disease. (Figs. 10 and 11.) He was treated on a convex frame and subsequently with plaster-of-Paris jackets. Coincident with this and probably as a result of the treatment he improved clinically and the roentgenogram (Fig. 12) shows marked regression.

The etiology of vertebral epiphyseal disease is as undecided as that of Legg's, Koehler's or Osgood-Schlatter's disease. Delahaye quotes Delpèche's Law[1] to the effect that excessive pressure causes an arrest or diminution of the activity of the epiphyseal cartilages, and diminished pressure causes hyperactivity. Therefore any static disturbance causing unequal pressure upon the vertebral epiphyses will cause unequal growth. This is further borne out by the statistics given by Dr. Royal Whitman[9] who says that in about 15 per cent. of spinal deformities the causes are: (1) deformity of other parts such as torticollis and distortion of the lower extremities; (2) diseases of the nervous system, such as poliomyelitis; (3) inequality of the lower extremities; (4) diseases of the thoracic organs, such as empyema; (5) Pott's Disease, fracture of the spine, sacro-iliac disease, and sciatic or lumbar neuritis; (6) occupations demanding habitual inclinations of the body; (7) congenital deformities, such as cervical ribs, elevated

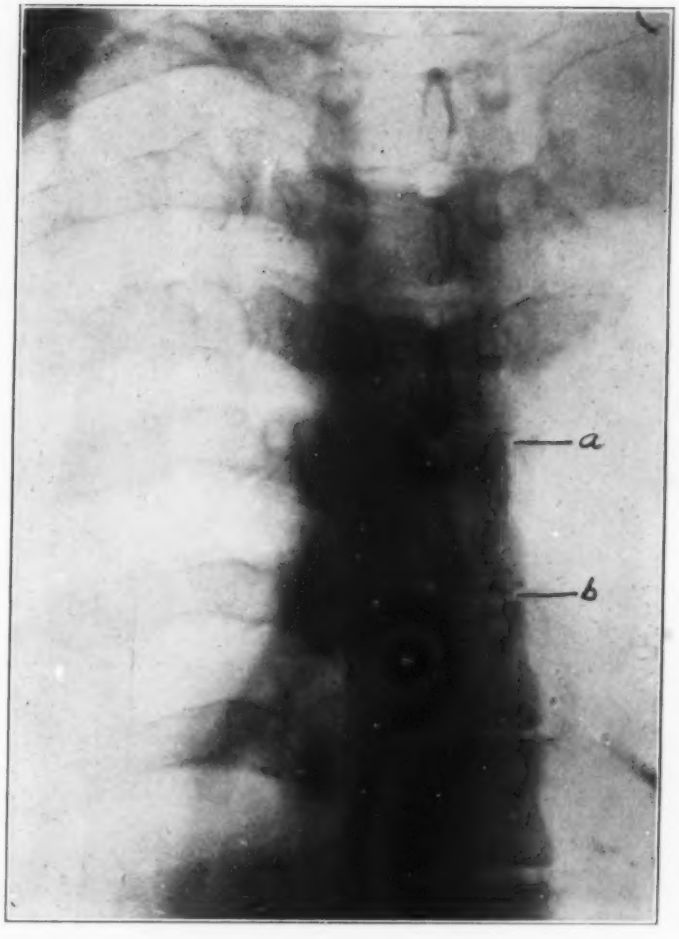

FIG. 8

Spine of 51-year-old man having a posterior curvature ever since he can remember and backache following a recent trauma. The changes here noted are typical of those in the late stages: (a) the indistinctness of the upper dorsal intervertebral spaces, (b) the mottling and the striated appearance.

FIG. 9

Lateral view of Fig. 8. Compare with Fig. 6. (a) Thickened, sclerosed, irregular vertebral borders. Patient has in addition osteoarthritic changes which we think are distinct from this condition. This probably represents the final adult form of Osteochondritis Vertebrae Juvenilis.

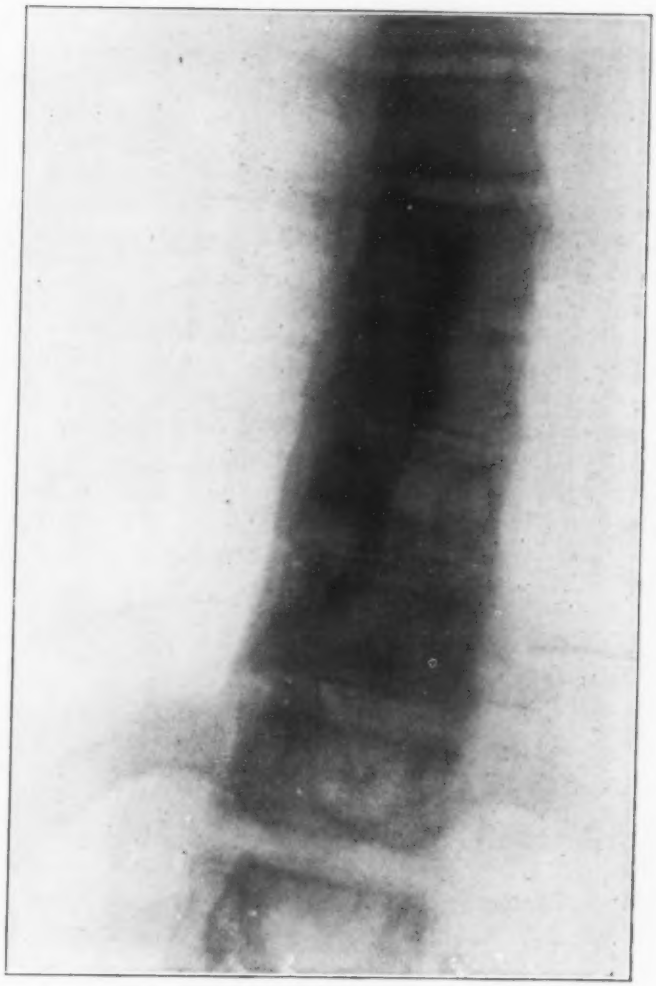

FIG. 10

Paul H. (See Case Histories.) The intervertebral spaces at the extremes of the picture are larger than in the intervening area. The intervertebral spaces in the middle are diminished in size, indistinct, mottled, and striated. The vertebral outlines are indistinct.

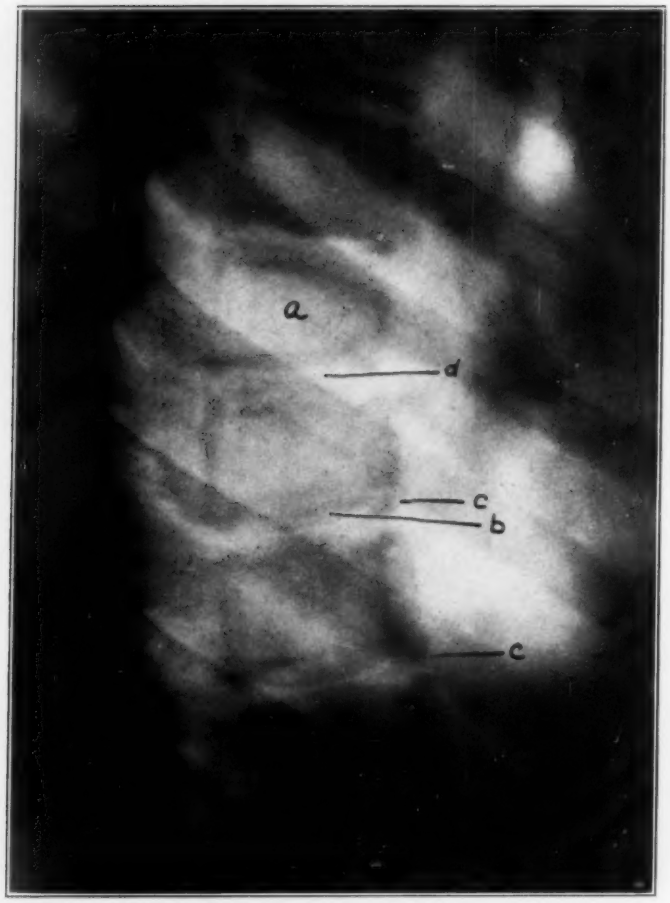

FIG. 11

Lateral view of Fig. 10. (a) The bodies are wedge shaped; (b) the vertebral outlines are irregular, frayed, and moth eaten; (c) the epiphyses are enlarged and frayed; (d) the intervertebral spaces are hazy and mottled.

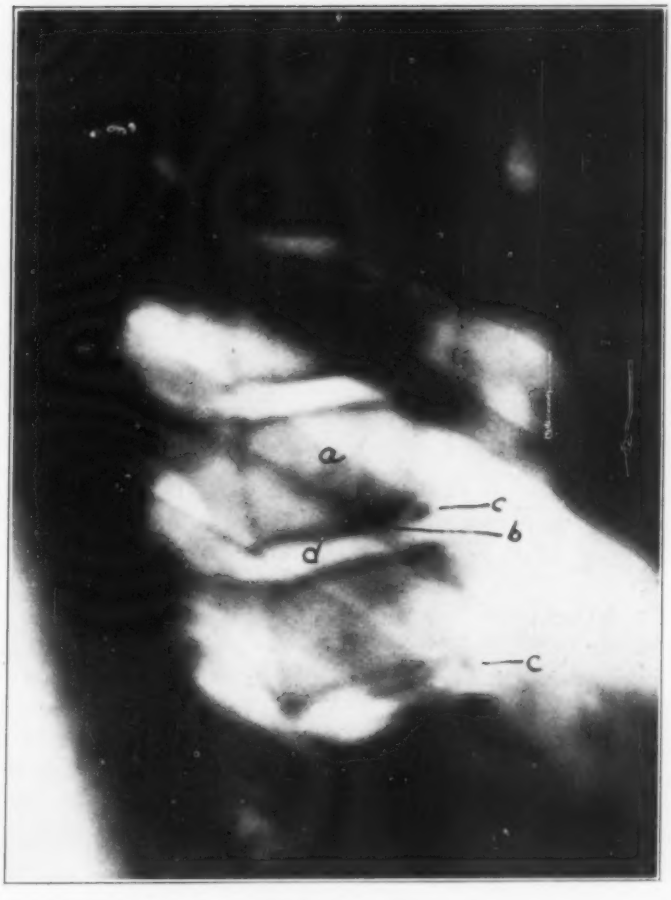

FIG. 12

Same as Fig. 11. Four months later, showing regressive changes. (a) The bodies have lost their wedge shapes; (b) the vertebral outlines are more regular, but thickened and sclerosed; (c) the epiphyses are smaller and more regular; (d) the intervertebral spaces are clearer.

scapulae, and malformations of the vertebrae; and (8) rachitic deformities. These conditions all represent states in which there is unequal pressure on the epiphyses causing unequal growth and consequent deformity. Their pathogenesis is explained on the basis of Delpèche's Law.

There remains about 85 per cent. of cases, the cause of which is as yet unknown. Like all juxta-epiphyseal areas, those of the vertebrae are congested and therefore a good medium for the location and the development of micro-organisms. We can readily conceive that organisms may lodge on either side of the epiphyseal cartilages and then influence the subsequent course in one of two ways. First, they might set up a very low infectious process and by its irritation and consequent congestion cause hyperactivity and premature ossification in an irregular fashion. Second, these organisms may be of such low virulence, or even avirulent, that they act merely as emboli which interfere with the circulation and thus cause a necrosis in the epiphyseal areas. The superincumbent weight would then cause minute compression fractures with resultant deformity. Because of the hampered circulation, healing would naturally be slow, thus allowing an opportunity for the deformity to be established. Once the deformity is there, be it due either to an hypertrophy of the epiphyses subsequent to premature ossification or to a malformation due to necrosis, deviation of the spine will result and may increase in accordance with Delpèche's Law.

I believe, however, that in this type of disease, micro-organisms plus superincumbent weight or strain of one sort or another are necessary to produce deformity. All the areas of epiphyseal involvement that up to now have been described are subject to great stress and strain. One has only to mention Koehler's disease of the tarsal scaphoid, Osgood-Schlatter's disease, Legg's disease, vertebral epiphysitis, and the other similar well-known conditions to realize that in all of these the areas of derangement are subject to great stress and strain. One might further add that this type of epiphyseal involvement is very rare in the upper extremities because there is less opportunity for strain in those parts of the body.

In 1921 Scheuermann[8] described a similar condition resulting in the painful kyphosis of adolescence. He draws a parallel between this and Legg's disease and suggests a parallel name: Osteochondritis Deformans Juvenilis Dorsi. Scheuermann's designation of this entity is a good one, but entirely too limiting. It is true that the disease seems to involve the dorsal spine almost exclusively. From the very nature of the disease, however, there is reason to believe that other than the dorsal vertebrae

may be affected. This is borne out by the clinical findings referable to the cervical and lumbar spines. In addition we are now observing a case in which the lumbar as well as the dorsal vertebrae are affected. Furthermore, all cases do not necessarily develop deformity, which is only secondary and dependent upon additional factors. Some of our cases show regression without any deformity of the vertebrae. It appears, therefore, that a more comprehensive name is desirable. Osteochondritis Juvenilis Vertebrae is more expressive and probably more correct.

CONCLUSIONS

(1) Normally, the superior and inferior vertebral epiphyses appear at about eleven and one-half years of age.

(2) Any gross deviation from the time at which these epiphyses appear, any deviation from their order of appearance, the presence of tenderness and abnormal X-ray findings are pathologic.

(3) The pathologic changes seen in the roentgenogram are as follows: The epiphyses become enlarged, moth eaten, frayed, and indistinct; the intervertebral spaces become cloudy, mottled, and irregular; the vertebral outlines become indistinct; all of these parts then tend to fuse into one indistinguishable mass. This is followed by the stage of regression in which the process is reversed.

(4) These abnormalities are found in a disease entity, occurring between the ages of ten and twenty-one and characterized by sensations of fatigue, backache, tenderness of epiphyses, and characteristic roentgenographic appearances.

(5) Many of these cases develop deformities of the spine.

(6) Deformities of the spine due to known causes do not present the above findings.

(7) The etiology is unknown. There is evidence leading to the belief that it is a very low grade infection in the spine.

(8) Stress and strain constitute additional factors which aid in the production of deformity.

(9) The condition is analogous to Legg's disease, Osgood-Schlatter's disease, Koehler's disease, and similar conditions, and forms part of a greater entity: Multiple Epiphysitis of Adolescence.

In closing, I wish to thank Dr. Royal Whitman and Dr. Percy W. Roberts and their respective staffs for the use of their material and their co-operation. I am deeply indebted to Dr. Samuel Kleinberg, who has

patiently guided me, advised me, and constructively criticized me. I am grateful to Mr. Joseph Flick, the Superintendent of the Hospital, for extending to me the use of the X-ray Laboratory for the study of normal spines.

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DISCUSSION

Dr. Samuel Kleinberg, New York City: The affection of the spine described by Dr. Buchman is strongly analogous to Legg's and Perthes' disease of the hip. Just as we see in the hip, deformity of the capital epiphysis and pathology in the femoral neck, so we find changes in the spine in which the epiphyseal plates are altered in shape and structure, and the bodies of the vertebrae are changed in their outline and not infrequently deformed and wedge-shaped.

The morphological changes described by Dr. Buchman have been seen sufficiently often by him and other members of the staff at the Ruptured and Crippled Hospital to assure the accuracy of his observations and preclude the possibility of this being merely an occasional chance incidental or accidental finding. What we are troubled with is the determination of the exact relationship between vertebral epiphysitis and deformity of the spine. I agree with Dr. Buchman that vertebral epiphysitis may be a cause of spinal deformity. I am not certain, however, of how often it is the cause of idiopathic scoliosis. Vertebral epiphysitis is seen most commonly in the lower dorsal vertebrae. The upper dorsal, at least in lateral curvatures, are clear and unaffected. Now in idiopathic scoliosis the right dorsal, left lumbar type of curve forms sixty per cent. of all the curvatures. And in this type of deformity the third, fourth, and fifth dorsal vertebrae are always involved. Yet we rarely find in them evidences of vertebral epiphysitis. Similarly, while we see about seven per cent. of primary lumbar idiopathic curves, disease of the lumbar epiphyses has been noted in only two cases of the entire series of nearly ninety cases.

This entire subject is a very interesting one and has opened up many problems the solution of which will probably shed much light on the etiology of idiopathic scoliosis and may alter our methods of treatment. Since we have been on the lookout for instances of vertebral epiphysitis I have come across many young patients who had had pain in the back and legs, and tenderness of many of the epiphyses, including those of the spine, tibial tubercles, the tarsal scaphoid, and the iliac crests. These are evidently cases of multiple adolescent epiphysitis. There appears to me to be undoubtedly an

intimate relationship between Legg-Perthes' disease, Koehler's disease, Osgood-Schlatter's disease, and this affection of vertebral epiphysitis described by Buchman.

Dr. Philip Lewin, Chicago: Several years ago a girl was examined by Dr. Porter and myself and diagnosed as having tuberculosis of the lumbar spine. She was examined at the Children's Memorial Hospital and the same diagnosis was made. Later on she came to St. Luke's Hospital from The Spalding School for Crippled Children and was treated for tuberculosis. She had the classical symptoms, including a definite kyphos. When the Central States Orthopaedic Club met in Chicago, about four years ago, Dr. Porter asked me to demonstrate her as a case of tuberculosis of the spine evidently cured, with disappearance of the kyphos and with perfect motion in all directions. Roentgenograms recently made revealed what appeared to be a double transverse process on both sides of the fourth lumbar vertebra. It proved to be a composite vertebra about four-thirds the normal size. In reviewing the literature I found an article by Scheuermann of Copenhagen written in 1921 on the subject of kyphosis dorsalis juvenilis. Recently there appeared an article by Calvé reporting one case of his own and one of Brackett's, both of which had been diagnosed tuberculosis. It seemed to me that we were justified in concluding that ours was a case of vertebral epiphysitis, and a description with roentgenograms will appear in an early number of the *Annals of Surgery*. I believe vertebral epiphysitis is analogous to Legg-Calvé-Perthes' disease of the hip; to Osgood-Schlatter's condition of the upper tibial epiphysis; to Köhler's tarsal scaphoiditis; to Freiberg's infraction of the metatarsal head, to carpal scaphoiditis, and to apophysitis of the os calcis. Recently Stern of Cleveland demonstrated before the Clinical Orthopaedic Society a similar condition in the lower tibial epiphysis.

Dr. F. J. Gaenslen, Milwaukee, Wis.: I believe the recognition of this condition as a definite type of spinal lesion marks a distinct advance. Many of you were present at the Boston meeting in 1921 when Dr. Lovett had thrown on the screen a large number of X-ray plates with undiagnosed lesions. Among them were several of the type in question and I recalled having seen similar cases in my own practice in which, of course, I could make no diagnosis.

What I want to speak about particularly is the difficulty in making a diagnosis in cases where there is a very marked disappearance of a single vertebra. I have one such case under observation now. This patient, whom I first saw about two years ago, had a wedging of one vertebra, the first lumbar, in which I made a diagnosis of tuberculosis. In addition he had a tuberculous chorio-retinitis, the diagnosis being made by two prominent ophthalmologists. Contrary to my usual procedure, I treated this patient conservatively because there was an indication of a slight peculiarity in the epiphyses of several vertebrae above and below the one chiefly involved. This made me question the correctness of the diagnosis. This patient is making an excellent recovery.

I believe that some of the round backs we see in old people are of this type.

A word as to treatment. It would seem that relief of weight bearing for a long period of time is very important. A plaster bed at night and a brace during the day should meet requirements. I have tried to keep the musculature of patients so treated in good condition by having them walk on all fours in the quadruped position, including in this exercise turning to the right and left and in addition hyperextension. During the prolonged period of rest intended to protect the vertebrae from further destruction, such exercises or attention to the musculature is essential.

Dr. Buchman's paper must be regarded as a very valuable contribution.

Dr. A. Bruce Gill, Philadelphia: I have with me a roentgenogram of the spine of the case just mentioned by Dr. Gaenslen and I shall leave it on the Secretary's desk for your examination. In this film will be seen the abnormal development of the vertebrae adjacent to the upper and lower epiphyses of the bodies, particularly along the anterior aspect of the bodies. The tendency to wedge-shaped development of the bodies is apparent. This condition, of course, leads to the kyphosis which is a sign of this condition. I have seen several other cases like this one, only not quite so well developed.

I agree with Dr. Gaenslen that the treatment should consist of continued hyperextension of the spine to remove the weight from the softened or non-developed areas along the anterior aspect of the vertebrae, and in exercises to strengthen the posterior spinal muscles. The pain which I have observed in these patients seems to be due to muscle strain, as the points of tenderness are in the gluteal muscles and along the erector spinae muscles. Baking and massage in addition to proper support by a brace will tend to relieve the pain and tenderness which is present.

Dr. J. T. Rugh, Philadelphia, Pa.: Mention has been made of the possible confusion of this disease with tuberculosis. I merely want to call attention to the differentiation of the roentgenogram of tuberculosis from the other. In tuberculosis there is early absorption of the intervertebral discs, which is not present in these cases.

Dr. Joseph Buchman, (closing the discussion): Allow me to differentiate the cases mentioned by Dr. Gallie and Dr. Lewin from the cases presented. They probably all belong to the same family of disease entities. Dr. Calvé's and Dr. Brackett's patients were two and a half and seven years old respectively. Dr. Gallie's patient was five years old. The superior and inferior vertebral epiphyses do not appear before eleven years of age. These cases probably represent an involvement of the centrum of the vertebra, while my cases represent an involvement of the superior and inferior epiphyses of the body of the vertebra. These conditions are similar but the location of the affection is different.

CHANGES IN THE ARTICULAR SURFACES IN TUBERCULOUS ARTHRITIS

BY D. B. PHEMISTER, M.D., CHICAGO

In a discussion of the changes in the articular surfaces in tuberculous arthritis, the changes in articular cartilage may be considered separately from those in the bone, since the two do not always proceed hand in hand. The cartilage is always involved secondarily, while the bone may be the primary seat of involvement and thus present both primary and secondary changes.

Articular cartilage may be affected by the direct action of tubercle toxins, by tuberculous granulation tissues, and by pressure erosion in opposing articular surfaces. The relative rôles of these three agencies vary according to the severity of the case, the duration of the disease, and the region of articular cartilage under consideration. In the early stages of the disease, the tuberculous infection is rarely of sufficient virulence to produce necrosis of large areas of articular cartilage, as is the case in pyogenic arthritis. The cartilage usually remains alive and, when so, it is not subject to destruction by erosive action. The most important method of destruction at this stage of the disease is by the action of tuberculous granulation tissue which attacks the living articular cartilage and destroys it. The articular cartilage may be attacked either along its free articular surface or along its surface of attachment to the bony cortex. Where articular cartilages of the opposing ends of the bones are in contact in only a portion of their extent, leaving areas of considerable size that are unopposed, the first destruction of cartilage is usually by granulations growing over the surfaces of the unopposed regions. They come from the involved synovial membrane about the margins of the articular cartilage and gradually destroy the latter along its free surface. Movement in the joint with friction of opposing articular cartilages tends to rub off the overgrowing granulations and limit their extent. As the range of motion is reduced and the ligaments of the joint are destroyed or relaxed, the amount of surface overgrowth and destruction increases. The amount of surface overgrowth and the depth of cartilage destruction vary also with the severity of the tuberculous infection. In mild tuberculosis, where the over-

growing granulations retain their vitality and where there is little necrosis and caseation, the cartilage will be progressively attacked over a long period of time and may be destroyed in its entire thickness in its unopposed regions, while in the regions of contact of opposing articular surfaces the cartilage is alive and in a fair state of preservation.

When, however, the tuberculous infection is severe, two changes may come about which greatly alter the picture from that which is seen in the less severe forms. First, there may be caseation of the tuberculous granulations, and those overgrowing the surfaces of the articular cartilage are equally affected with those involving the synovial membrane. This early caseation may either entirely prevent the overgrowth of granulations upon the cartilage or rapidly remove those that have formed, so that destruction by direct attack of tuberculous tissue along the free surface of the cartilage is either very limited in amount or entirely lacking. A second effect of severe tuberculous arthritis may be the production of necrosis of large areas of articular cartilage, partly by the action of the tubercle toxins and partly by the cutting off of nutrition from the normal synovial fluid. There is good evidence, such as Nussbaum's[1] experiments, that the greater part of the layer of articular cartilage derives its nutriment from the synovial fluid. When the infection is sufficiently severe to kill articular cartilage, it may do so in the regions of contact and pressure of opposed articular surfaces, as is the case in severe pyogenic arthritis.

A second region in which granulations develop in tuberculous arthritis is the superficial portion of bone beneath the articular cartilage. Here a thin layer of subchondral granulations forms which absorbs the bony articular cortex and the deeper layer of cartilage, leading finally to its detachment, with marked thinning or perforation. It is a curious fact that histologically this tissue differs markedly from the tuberculous granulation tissue which develops in the synovial membrane and overgrows the free articular surface. The latter contains round cells, epithelioid cells, and giant cells and presents the usual cytologic picture of tuberculosis. However, the subchondral granulations, except those about the margins, are not tuberculous in appearance, containing capillaries, fibroblasts, moderate numbers of round cells, and no tubercles with epithelioid and giant cells. The reason for the difference between the surface granulations and the subchondral granulations is not entirely clear, but it may be that the two types of tissue form in response to different stimuli: the granulations in the synovial lining form in response to the tuberculous infection, while those undermining the articular cartilage probably form secondary to death of the cartilage, as a foreign body reaction to the dead

tissue, rather than as a result of invasion of the subchondral regions by tubercle bacilli. They are somewhat similar to simple granulation tissues which form about foreign bodies. Since they do not contain tubercles, they do not usually undergo coagulation necrosis and caseation, and consequently they may continue to absorb, detach, and penetrate the articular cartilage from underneath at a time when surface destruction of

FIG. 1

Caseous tuberculous arthritis of nine months' standing. Shadow of articular cortex absent as result of absorption of cortex by subchondral granulations, but cartilage space of joint preserved, as cartilage discs were present, although somewhat thinned.

cartilage has been arrested by the occurrence of caseation in the synovial and surface granulations. The following is a case in point:

CASE REPORT. Male, age 21, suffering for nine months with tuberculous lymphadenitis of right cervical and axillary glands and with tuberculous arthritis of left knee, which had prevented use of the limb for six months. The left knee was flexed to 35 degrees, immobile, markedly swollen and painful. Radiograms of the knee showed regional bone atrophy with either marked reduction in density of or complete loss of shadow of articular cortex on femur, tibia, and patella. The cartilage space of the joint was of normal width between lateral condyle and lateral tuberosity, but slightly narrowed

between mesial condyle and mesial tuberosity (Figure 1). The joint was resected; extensive caseous tuberculous synovitis was encountered, with numerous perforations of the capsule and cold abscesses about the joint. There were practically no tuberculous granulations overgrowing the surface of the articular cartilage on either femur or tibia, and there was only slight superficial and marginal erosion of cartilage in the regions where overgrowth is usually encountered. There was marginal overgrowth of granulations on the patellar articular surface, but they were caseous and were producing no surface erosion. Subchondral granulations were present beneath almost the entire extent of articular cartilage on all three bones and in many places had completely detached cartilage from bone. On both mesial and lateral tuberosity, but especially on the lateral, the subchondral granulations had markedly thinned and perforated the layer of articular cartilage, particularly in its central portion. In fact, most of the cartilage in the region of pressure on the lateral tuberosity was destroyed. The peripheral portions of the cartilage over the tuberosities showed fewer subchondral granulations and less destruction. A similar though less marked thinning and destruction of articular cartilage from subchondral granulations was present on the posterior and inferior articular surfaces of the condyles of the femur where they came in contact with the flexed tibia. There was less undermining and detachment of articular cartilage on the femur between these regions and the patellar region, where it was not in contact with opposing articular cartilage. Subchondral granulations had detached the central portion of the patellar articular cartilage, but it was largely adherent about the periphery (Figure 2). Microscopic examination of the tuberculous synovitis showed tubercle formation with extensive caseation. Microscopic examination of the subchondral regions showed granulation tissue with absence of tubercles, but with hemorrhage and necrosis in many places.

This was a case of severe tuberculous arthritis with extensive involvement of both soft parts and articular surfaces. The tuberculous tissue in the synovial and parasynovial structures had undergone marked caseation and this had prevented it from destroying articular cartilage along the free surfaces to any appreciable extent. Subchondral granulations had formed more extensively in the regions of contact and pressure of the opposing articular surfaces than elsewhere. This was probably the result of earlier death of cartilage at these points than at other places in the joint. The subchondral granulations did not present histologically the same tuberculous picture as seen in the synovia and were much less extensively degenerated. In a previous article [2] I described and gave illustrations of the effects of tuberculous arthritis on articular cartilage, but failed to distinguish the special features of the caseous form just mentioned and to emphasize the extent of action of the subchondral granulations in some cases.

When secondary infection of a tuberculous joint occurs along a fistulous tract, the changes incident to pyogenic arthritis and described in the previous article may be superimposed on those already produced by the tuberculosis. In this event, articular cartilage may be rapidly lost

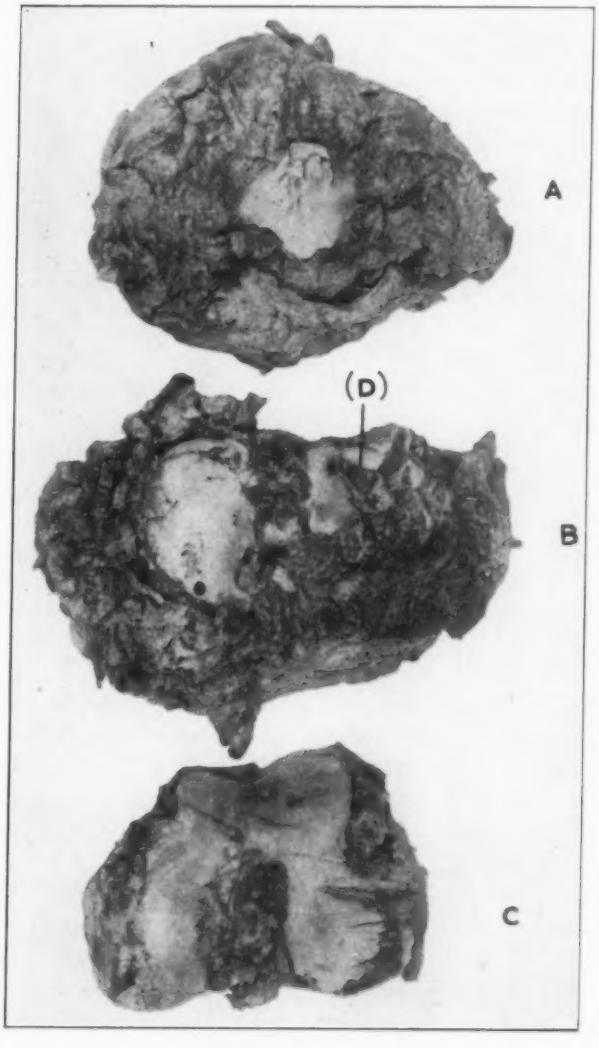

FIG. 2

Resected joint shown in Figure 1. (a) Patella, (b) tibia, (c) femur. Cartilage most extensively destroyed on lateral tuberosity (d) of tibia in the region of contact and pressure by the action of subchondral granulations and by erosion.

at the points of contact and pressure, where it might have persisted much longer had there been no secondary pyogenic infection.

In tuberculous joints showing marked caseation or with little or no

FIG. 3

Sagittal section of patella, showing cartilage attached to bone at its periphery, but detached centrally by subchondral granulations.

articular surface that is not in contact with opposing articular surfaces, almost the entire destruction of the cartilage may be by the subchondral granulations. Marginal undermining of the articular cartilage may be seen in some places by typical tuberculous granulations growing in from the synovia.

König[3] believed that the overgrowth of granulations upon free articular surfaces was preceded by the deposition of a layer of fibrin or pannus. Microscopic examination of tissue overgrowths usually does not confirm this opinion. It is true, however, that fibrin may be deposited on surfaces that pour out the tuberculous exudate and may persist for a very long time, because of the absence of polymorphonuclear leucocytes and consequently of proteolytic ferments, which would bring about its removal. It is for this reason that rice bodies are found almost exclusively in tuberculous infections of serous lined cavities and that dead cartilage may persist for months or years in a tuberculous joint without showing signs of digestion. Proliferation of cartilage at its margins, with subsequent ossification and spur formation, does not occur in tuberculous, as in chronic pyogenic or deforming arthritis. Spurs occasionally form from the periosteum of the epiphysis, but they are situated at least a short distance back from the articular margin.

Changes in the bone along the articular surfaces. In considering the changes in the bone along the articular surfaces, a distinction must be made between those which occur at a point of primary osseous involvement and those which arise secondarily from spread of the infection along the articular surfaces. In tuberculous arthritis the seat of primary infection is in the bone in some cases and in the synovial membrane in others. The relative frequency with which it begins in the bone and in the synovial membrane is not accurately known, as at the time of examination it is often difficult to determine the primary point of involvement because of the extensive secondary changes that have arisen from spread of the infection throughout the joint. The older statistics, as of Volkmann, König, and Krause, concerning the relative frequency of the primary osseous and primary synovial tuberculous arthritis are based solely upon anatomic studies, many of which were of joints in the advanced stages of the disease. Early in the disease the radiogram will show the point of primary involvement, when it is osseous, in a considerable percentage of cases, particularly in children. It has not been fully utilized in conjunction with pathologic studies for the purpose of more accurately determining the primary point of infection. Many errors have been made in the past by confusing primary foci of infection in the bone with areas of secondary bony invasion. This is one reason why the percentage of primary osseous tuberculosis is often given too high.

When the disease begins in the bone bordering on articular surface, there develop primary changes at the point of lodgment of the bacteria and there may be secondary changes along the rest of the bony articular sur-

face from spread of the infection into the joint. The changes in the bony articular surface are entirely secondary in those cases where the disease begins either in the synovial membrane or in the bone away from the articular surface, as in the end of the shaft with subsequent rupture into a recess of the joint.

The primary bony focus bordering on articular surface may be an irregular one, suggesting bacterial localization without arterial blockage, or it may be cone-shaped with the base of the cone formed by the articular cortex. The latter is the result of obstruction of an end artery with secondary infection of an area whose blood supply becomes inadequate. König[3] attributed this to embolism from a caseous mass in the pulmonary veins, while others, as Orth[5] and M. B. Schmidt,[6] believe that bacilli alone may lodge in the finer vessels with resultant infarction and infection of the infarct. Tuberculous infarcts are perhaps commoner in the metaphyses than in the epiphyses, but they are more apt to persist as sequestra in the epiphyses, particularly of adolescents and adults. Nussbaum[7] has recently restudied the blood supply of the epiphyses and metaphyses of bones and claims that metaphyseal arteries are end arteries, while epiphyseal arteries are not. If this observation is correct, tuberculous infarcts should be much commoner in the metaphysis than in the epiphysis during the growing period.

The primary epiphyseal focus bordering on the articular surface varies in size. It may be no larger than a grain of wheat or a pea, in which case it may easily escape detection unless the joint is examined pathologically at an early date, since secondary changes in other portions of articular cortex may soon equal it in extent. In other cases, and particularly where there is a cone-shaped infarct, the involved area may be large and measure two or three centimeters in its greatest dimension.

The fate of the bone in the area of primary osseous involvement varies according to its size and location. In small areas the bone may be broken down rapidly as the focus spreads, leaving a cavity that is filled with tuberculous granulations or necrotic débris. Bone sand may also be present from lack of complete destruction of cancellous bone. Such areas are seen especially in the diaphysis. In other cases large areas are involved and the tuberculous tissue of the cancellous spaces undergoes early necrosis and caseation, leaving the dead bone practically intact. A cone-shaped infarct with its base bordering on the articular surface first undergoes sequestration. Occasionally the granulations then gradually absorb the sequestrum and a deep hole is left in the epiphysis. Usually this does not occur, and the dead bone remains stationary both as to size

and density over long periods of time. The surrounding living bone usually decreases in density as the result of prolonged atrophy of disuse, so that as time goes on the dead area casts a heavier shadow in the radiogram than the surrounding living bone.

The cartilage overlying the area of primary osseous involvement dies, and, in case the granulations absorb the dead bone, they usually also absorb a considerable proportion or all of the dead cartilage, so that the

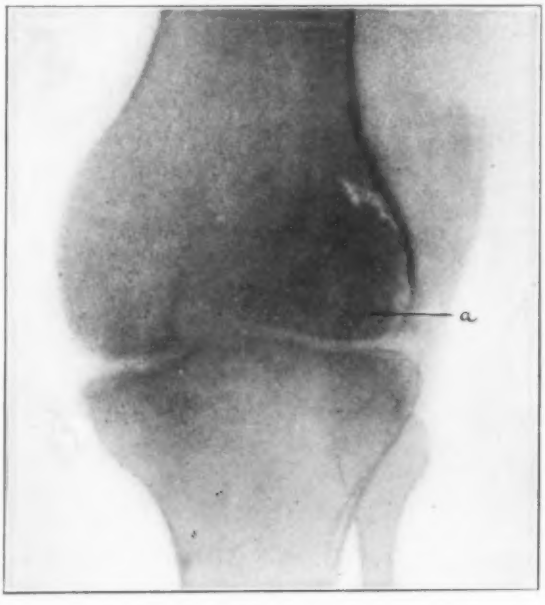

FIG. 4

Tuberculous knee with primary cone shaped sequestrum (a) in external condyle.

cavity comes to communicate with the joint. In some cases the cartilage will not be found penetrated and it is impossible to locate the necrotic area by inspection of the joint surface, in which case the disease may spread into the joint from the side and produce secondary tuberculous arthritis. Where the bone does not break down and subsequently becomes sequestrated, its overlying dead articular cartilage cannot be attacked by granulations from beneath, and it may persist for months or years, unless it is eroded by friction of the opposing articular surface. I have found portions of dead cartilage covering the articular surface of a sequestrum

six years after death of the area had occurred. Radiograms showing a cone shaped area of bone denser than the surrounding bone and with a shadow of articular cortex preserved along its base are almost positive evidence of the presence of a joint sequestrum. Figure 4 shows the radiographic appearance of a tuberculous joint of six years' standing in a man of twenty-

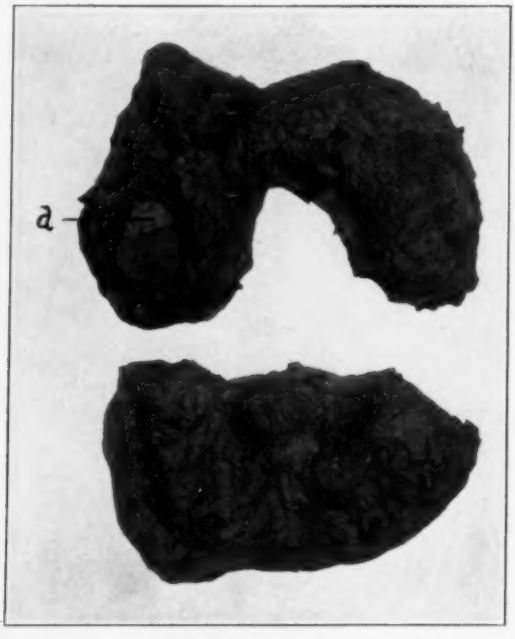

FIG. 5

Resected specimens from case in Figure 4, showing articular cortex and portion of cartilage (a) preserved on base of sequestrum, but lost elsewhere in the joint.

six. The infection was primarily osseous and produced a cone shaped sequestrum in the external condyle of the femur. The sequestrum is denser than the surrounding living bone and presents a shadow of bony articular cortex, which is absent in the rest of the joint. The resected specimen (Figure 5) showed a sequestrum of the density of normal bone with articular cortex intact along its base and a moderate amount of dead articular cartilage still attached to it. Both articular cartilage and bony cortex were

missing on nearly all of the rest of the joint surface as the result of spread of the infection throughout the joint.

Secondary changes along the articular surfaces of the bones develop from spread of the tuberculous infection from the primary point of involvement, whether it be located in the bone or in the synovial lining. They consist in absorption of the articular cortex by the development of superficial granulations, a condition which the older writers designated as "caries," or in secondary invasion of underlying bone, producing more or less extensive areas of bone necrosis. As stated in the discussion of cartilage destruction, the articular cortex may be destroyed by subchondral granulations, by marginal granulations, or by surface granulations which have first destroyed the overlying articular cartilage.

After breaking down the bony articular cortex, the granulations may absorb the spongy bone, producing marked grooves and irregularities in the surface of the end of the bone. They may caseate and liquefy, leaving a bare bony surface. A variable amount of bone may be lost from the ends by pressure erosion. If healing sets in, a fibrous layer may form over the bony ends and fibrous ankylosis result. An irregular bony cortex may reform with time, or bony ankylosis may follow, but it is less common than fibrous ankylosis.

There may be secondary penetration of the ends of the bones by the tuberculous process, producing extensive and deep areas of necrosis bordering on the joint surface. It occurs in the severer forms of the disease, and the point of invasion is nearly always in the zones of contact and greatest pressure in the joint. It may occur either before or after the articular cartilage has been destroyed. Undoubtedly the damaging influence of pressure is instrumental in producing bony invasion, and if the bone is invaded on one side of the joint it is apt to be invaded on the other side. These areas are so large that the dead bone is rarely absorbed, but is gradually sequestrated. When the process is bilateral, "kissing sequestra" result. If cartilage is present on the articular surface at the time of invasion of the underlying bone, it will be killed, but it may persist for some time before it is destroyed by erosion. If a large sequestrum forms and a portion of it is not in contact with the opposite bone of the joint, dead cartilage may remain on that surface for years, because of the fact that granulations cannot readily get at it and because proteolytic ferments that might digest it are absent in tuberculous exudates. If secondary invasion occurs relatively early, the bone in the necrotic areas will be little atrophied and subsequent atrophy in the living bone of the region will reduce its density below that of the dead bone, so that the dead

areas cast heavier shadows in the radiogram than the living bone. When articular cortex is present at the time of invasion, it will be preserved on the secondary sequestrum the same as on a primary one. The secondary sequestra may be oval or cone-shaped and resemble very closely the primary cone-shaped sequestra that are the result of arterial obstruction. However, the site of the necrotic area at the point of greatest pressure in the joint, the fact that the invasion is usually bilateral, producing "kissing sequestra," and the evidences of a certain amount of atrophy in the dead bone, which had taken place before the tuberculous invasion, are sufficient proof that such lesions are the result of secondary bony invasion. They have frequently been mistaken for primary foci of infection.

If the invasion occurs later, when marked atrophy is present and after articular cartilage and cortex have been destroyed, the necrotic areas will possess the same low density as the surrounding living bone. These areas may gradually be sequestrated, so that a line of separation may be seen in the radiogram and make it possible to recognize them, but usually this is not the case and they are discovered only after the joint has been opened. Here also the invasion is usually bilateral, which makes the evidence complete that kissing areas of necrosis or sequestra arise as the result of secondary tuberculous invasion of the bone. Pathological and radiographic illustrations of these secondary changes in the bone are to be found in my previous article.

SUMMARY

In the earlier stages of tuberculous arthritis, in joints with both free and contacted articular surfaces, the articular cartilage is usually destroyed most extensively along its free articular surfaces by granulations which overgrow it from the surrounding synovial membrane. In the regions of contact and pressure of articular surfaces, surface destruction by granulations does not take place and the cartilage is preserved longest. As the disease progresses, subchondral granulations develop which absorb articular cortex and attack the cartilage from beneath. In severe tuberculous arthritis there may be early necrosis and caseation of the overgrowing synovial granulations, so that there is little or no destruction of articular cartilage along its free surfaces. In this event the destruction of articular cartilage is brought about mainly by the subchondral granulations, which do not undergo early necrosis and caseation and do not present the usual histologic picture of tuberculous tissue. The bony involvement along the articular surface may be either primary or secondary. When primary, the dead bone may break down, leaving a cavity, or may persist and form a

sequestrum which has articular cortex and in some instances cartilage preserved on it and is denser than the surrounding living bone which subsequently atrophies. Secondary involvement of bone along the articular surfaces may lead either to destruction of the entire articular cortex by superficial caries or to more or less extensive and deep areas of necrosis at the points of greatest pressure in the joint. This deep invasion is often bilateral and is followed by the formation of "kissing sequestra," which may be mistaken for primary foci of osseous infection.

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DISCUSSION

Dr. Nathaniel Allison, Boston: Dr. Phemister's paper has put this subject so nicely before us that there is nothing that I can say except that I admire his observations. These observations which you have heard are original, especially the observations on the proteolytic power of pus-producing organisms as compared with that of tuberculosis, which has no such power and in which as we have observed the cartilage persists for long periods of time. I think this observation is a most valuable one and since Dr. Phemister first made it about a year or two ago, I have been trying to think what it might mean clinically. I would not want to introduce that into this discussion. He has in one of his papers made a slight reference to the clinical significance of this persistence of the cartilage. He has shown that the cartilage persists in tuberculosis on the joints where pressure and contact exist; the cartilage is destroyed on the free surface and the margins first. If this is true, it would seem that some of the clinical things that are done for tuberculous joints might not be the best things to do for these joints; in other words, if we could distract these joint surfaces, which is impossible, then we are laying open that cartilaginous surface to invasion from the granulations on that surface. Of course, this has no bearing on the subendothelial granulations which come from the marrow. It puts before us a very definite line of thought and it is such a cleancut, well given description that I think every one who heard it will remember it and perhaps think about it. The material which Dr. Phemister had was simply material which was removed from the ordinary operative treatment of cases clinically, and his industry and his power of observation, just using these joint surfaces,

has placed before us this very admirable demonstration of many new things and a new line of thought.

Dr. E. W. Ryerson, Chicago: You must realize that this work of Dr. Phemister has cleaned up the question of why tuberculous joints do not readily form bony ankylosis. It has long been a matter of observation that a patient may carry a tuberculous knee for ten, fifteen, or twenty years without the slightest attempt at a bony ankylosis, and, in the opinion of many of us a bony ankylosis is the only way in which such joints may become well. Phemister's observation opens up an enormous field for thought and practically proves that operation is the most desirable form of treatment.

Dr. D. B. Phemister, Chicago (closing the discussion): These findings suggest that weight extension of the limb in the average case of tuberculous arthritis would have little or no influence on the preservation of articular cartilage by way of preventing pressure erosion of cartilage on opposed articular surfaces. If the surfaces could be pulled apart by weight extension, surface granulations might more easily attack and destroy the articular cartilage. This, however, is difficult of accomplishment, as shown by roentgenograms of joints under heavy extension. Tuberculous joints are benefited by weight extension rather from the rest that it produces than by the prevention of erosion of articular cartilage.

ACUTE SUPPURATIVE ARTHRITIS IN CHILDREN*

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INTRODUCTION

While acute suppurative arthritis is not a disease of great frequency in children, it carries with it the possibilities of such serious consequences to life, and to future function of the limb, as to render it worthy of careful consideration. Considerable difference of opinion exists as to the best method of treatment, and this confusion is accentuated by the absence in recent literature of reports of any considerable series of cases. At the present moment our conception of the subject is strongly influenced by ideas acquired during contact with war injuries. Arthritis occurring as the result of gunshot wounds is characterized by such severe infection and by the frequency of such complications as compound fractures into the joint, as to make it a problem almost separate from arthritis as seen in civil practice. There is need for a discussion of the whole subject, based upon the examination of a number of cases, in order that the indications for treatment may be clearly defined. Such an analysis of the condition in so far as it occurs in children, is presented in this thesis, in which is recorded the result of the examination of those cases of arthritis admitted to the Hospital for Sick Children, Toronto, during the past six years.

DEFINITION

Acute suppurative arthritis may be defined as an acute inflammation within a joint, arising from its infection by pyogenic organisms, leading to the formation of a purulent exudate within the joint and to greater or less injury to its structure and subsequent function. It is essentially a suppurative process, and must be so regarded and treated.

ETIOLOGY

Paths of Infection:

A joint becomes the seat of an acute suppurative infection as the result of the implantation of bacteria within its cavity in one of three ways.

*Presented at the meeting of the American Orthopaedic Association, May, 1925.

The organisms may be introduced into the joint directly from the exterior through the agency of a penetrating wound. They may reach the joint by extension from a neighboring focus of infection. Finally they may be implanted within the joint from a distant focus through the agency of the blood stream.

Direct implantation of the organisms into the joint through the agency of a penetrating wound is, in civil life, the least frequent of the modes in which suppurative arthritis arises. It occurred in 9.8 per cent. of the cases which form the basis of this paper. From the traumatic nature of the infection it is obvious that in civil life, only those joints most exposed to injury will suffer from arthritis from this cause. The deeply seated joints are protected by their situation. In all the examples of this path of invasion in the series reported in this thesis, the joint involved was the knee, all resulting from a fall upon some sharp object, such as a nail, thorn, or stone.

Infection of the joint by extension from some neighboring suppurative focus (occurring in 27.4 per cent. of the cases) is, in nearly every instance, the result of an osteomyelitis in one of the bones entering into the formation of the joint. Osteomyelitis is of such frequent occurrence during childhood and the infection is often of such virulence that invasion of the neighboring joint might be expected to be of common occurrence. In the majority of cases of osteomyelitis, however, the cartilage of the epiphyseal line constitutes an effective barrier to the spread of the infection in the direction of the neighboring joint, and the occurrence of arthritis is less frequent than might be expected. This is associated with the peculiar mode of spread of the infection in acute osteomyelitis. This disease starts in the cancellous bone on the diaphyseal side of the epiphyseal line. Its tendency to spread in all directions leads to a progressive involvement of the shaft of the bone until it reaches the space beneath the periosteum. The ease with which the accumulating pus can lift the periosteum from the cortex then determines its subperiosteal spread up the shaft. Spread towards the joint is limited by the barrier formed by the epiphyseal plate of cartilage and the dense attachment of the periosteum to the epiphyseal line. In those joints, however, in which part of the epiphyseal line and of the diaphysis are overlapped by the joint capsule, the infective material which collects beneath the periosteum may perforate that membrane and invade the joint directly. Thus, in the hip joint, osteomyelitis of the neck of the femur invariably leads to arthritis, since the whole of the epiphyseal line and the proximal part of the diaphysis are included within the joint cavity. Similarly in the knee joint, the manner in which the suprapatellar

pouch overlaps the epiphyseal line renders it easy for an osteomyelitis starting in the anterior part of the shaft to invade the joint. A similar relationship of the head of the radius to the elbow joint permits the extension from an osteomyelitis of the upper end of the radius into that joint.

Occasionally a joint may be infected from some neighboring focus other than osteomyelitis. Thus suppurative prepatellar bursitis may invade the knee joint, or an infected skin lesion in the neighborhood of a superficial joint may extend into it. The infrequency of these lesions in contrast to the common occurrence of osteomyelitis gives to the latter the more important place in the causation of arthritis.

Apart from the two paths of invasion discussed above, suppurative arthritis may commence as the result of invasion of the joint by organisms brought to it from some distant focus by the blood stream. This is the most frequent mode of infection, constituting 62.8 per cent. of the cases in this series, as compared with 27.4 per cent. arising by extension from a neighboring septic focus, and 9.8 per cent arising from penetrating wounds. In such cases a septicaemia must always be present and can usually be demonstrated. The primary foci giving rise to such septicaemias are of the most varied nature. Infected skin lesions of various types, e.g., boils, pustules, abrasions, and infected wounds, constitute an important group of primary foci, usually giving rise to staphylococcal septicaemias. Nasopharyngeal infections and otitis media are the common sources from which the streptococcal septicaemias arise, though they may also produce pneumococcal or influenzal infections.

In the haematogenous type of invasion of the joint trauma plays an important part. The localization in a particular joint of organisms which have been circulating in the blood stream is often, perhaps usually, determined by injury. A typical history is the following:

H. S. C. 32078. G. F. Male, age 2 years. Four days before admission he fell on his right knee. He complained of pain in the joint at the time, but this quickly subsided and he was able to walk. The skin was not injured. On the following day the knee was swollen and painful, and he was unable to move it or walk upon the leg. The temperature was 102. These symptoms continued with increasing severity up to the time of admission to the hospital. The night before coming into the hospital he had a convulsion. Examination showed the knee to be tender, fixed in flexion by muscle spasm, painful on movement, and its movement limited in range. The capsule was distended with fluid. Temperature was 104.6°. W. B. C. 10,000 (74 per cent. polymorphonuclears). Exploratory puncture revealed pus from which a staphylococcus was grown. Staphylococcus aureus was recovered from the blood. A bilateral anterior incision of the capsule was made on either side of patella and the leg fixed in a Thomas splint with extension. The temperature fell rapidly to normal. Recovery was complete in three months.

Such a history recurs with too great frequency and constancy to be a coincidence. Many such cases would have escaped an arthritis had they not suffered an injury coincident with the presence of organisms in the blood stream. The simultaneous occurrence of a traumatic lesion of a joint and a bacteraemia are the two factors necessary for the production of this type of arthritis.

While trauma plays an important part in the production of many cases of haematogenous arthritis, it is not always a causative agent. In those cases which occur during a septicaemia severe enough to cause symptoms, e.g., the septicaemias following otitis media, arthritis may arise without any appreciable trauma. In such cases the intensity of the bacteraemia is probably very much greater, and the resistance of the patient to the infecting organism much lower than in the case in which trauma plays a part.

INFECTING ORGANISMS:

The organism producing septic arthritis may be any one of an extremely varied list. By far the greatest number of cases are produced by the staphylococcus aureus or the haemolytic streptococcus. Less commonly, arthritis may be produced by influenza bacilli, pneumococci, colon bacilli, or, in fact, any of the pyogenic organisms.

Generally speaking, infections produced by the staphylococcus aureus are the most virulent and the most destructive, with those produced by the haemolytic streptococcus a close second. Infections by the influenza bacillus, pneumococcus, and colon bacillus, are less virulent and less destructive. Even in the staphylococcal cases, however, the severity of the arthritis is dependent greatly upon the balance between the resistance of the patient and the virulence of the particular strain of organisms. There may exist all degrees of severity, from extreme virulence to great attenuation. Among the streptococcal cases this tendency to individual variation is even more marked than among the staphylococcal cases.

In certain of the cases (9.8 per cent. in this series) culture of the purulent fluid removed from the joint is sterile, though clinically the joints present every sign of an acute arthritis. In some cases the failure to grow is due to the extreme attenuation of the infecting organism, as bacteria can be demonstrated on direct smear but fail to grow in ordinary culture media. In other cases the causative organism may be of an unusual type which cannot grow under ordinary cultural methods. An example of the latter type is the following case:

H. S. C. 26606. M. T. Female, age 12 years, was admitted with subacute osteomyelitis of left femur of six weeks' duration. The roentgenogram suggested syphilitic

periostitis, though the Wassermann later was found repeatedly to be negative. Eight days after admission, during which time the lesion had been treated as syphilitic, the knee suddenly became painful and swollen, and the temperature rose to 103. The joint was opened three days later, by bilateral anterior incisions on either side of the patella. A large quantity of very white pus containing polymorphonuclear leucocytes 95 per cent. was present. This was repeatedly sterile on culture, and when injected into a guinea pig failed to produce tuberculosis. The patient had a prolonged and stormy convalescence, ending with complete ankylosis of the knee in full extension.

SURGICAL PATHOLOGY

The comparative infrequency with which pathologic specimens are obtained renders difficult an accurate description of all the details of the surgical pathology. The infection starts in the synovial membrane lining the joint. This rapidly becomes inflamed, swollen, and oedematous. From its surface is poured out synovial fluid, plasma, and leucocytes, filling the joint cavity with a turbid fluid containing large numbers of polymorphonuclear leucocytes and much fibrin. The joint rapidly becomes filled with a glairy pus. If the infection is severe or prolonged, the endothelium lining the synovial membrane is destroyed, and its place taken by a mass of granulation tissue.

The changes occurring in the synovial membrane are of less importance than those occurring in the articular cartilage, since recovery of function can take place even after severe damage to the synovial membrane, while injury to the articular cartilage results in greater or less impairment of the function of the joint. Fortunately the articular cartilage is less readily involved than is the synovial membrane. It requires a severe, and particularly a prolonged, infection to cause death of any considerable amount of this structure. In children the great thickness of the articular cartilage renders its complete destruction, with resultant bony ankylosis, less likely than in adults. Moreover, its avascular nature and the presence of impermeable ground substance, result in the exposure of only the superficial cells to the action of the bacterial toxins.

As has been shown by Phemister, there are enzymes present in pus which are capable, under appropriate circumstances, of dissolving the intracellular ground substance of the articular cartilage. Prolonged contact of the cartilage with pus cannot fail to result in more or less dissolution of the cartilage. In addition the organisms inciting the arthritis more or less rapidly destroy the superficial cartilage cells, staphylococcus being the most potent in this respect. The dissolution of the ground substance and death of the cartilage cells goes on most rapidly at the margins of the articular surface, where the cartilage is overlapped by the pannus of

granulation tissue arising from the inflamed synovial membrane. Since the destruction of the cartilage takes place from its free surface and at a comparatively slow rate, the length of time the arthritis has existed without drainage is an important factor in determining the amount of destruction which will occur. The most important agent in limiting the destruction of the articular cartilage is early removal of the pus by drainage.

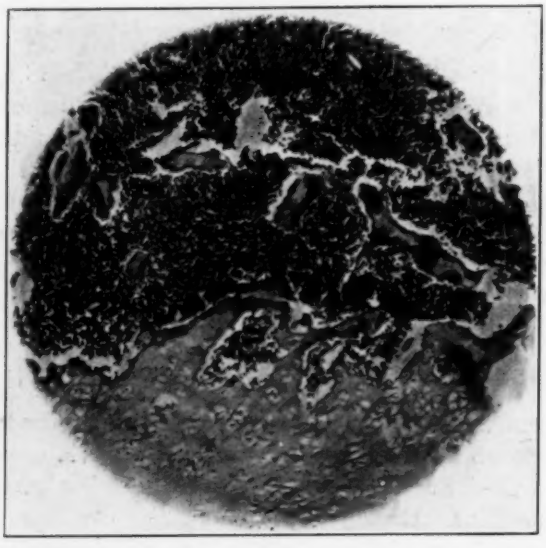

FIG. 1

High power photomicrograph of sterno clavicular joint involved in acute suppurative arthritis. The section has been made at the free surface of the articular cartilage, now covered with a layer of granulation tissue and leucocytes.

The destruction of the cartilage by the action of enzymes and bacteria is accentuated by the friction of the opposing surfaces on one another during movement and by the manner in which they are pressed together by muscle spasm. For this reason, as well as for others, fixation of the joint and extension are important aids in the treatment of the acute stage.

Microscopic sections of the joint during the acute stage of an arthritis (Fig. 1) show death of the superficial layers of cartilage cells as indicated by pyknosis and by failure of the nuclei to stain. The superficial surface of the cartilage is irregular in outline and is eroded by masses of granulation

tissue and polymorphonuclear leucocytes. In the cartilage immediately beneath its free surface, lacunae appear which are filled with polymorphonuclear leucocytes. The miscroscopic picture is that of destruction of the cartilage from its free surface.

In the majority of cases the inflammation is limited to structures that

FIG. 2

Radiograph of knee ankylosed as the result of haemolytic streptococcus arthritis. The cartilage from the posterior surface of patella and anterior surface of condyles of femur has been entirely destroyed, permitting bony fusion between the patella and femur. In addition marked damage has been sustained by the articular cartilage on tibia and femur.

are within the joint capsule. However, if the infection is severe or prolonged, the joint capsule may be destroyed and the infection invade the periarticular tissues. Abscesses then form in the intermuscular planes and these must be dealt with as separate infective foci.

With the establishment of adequate drainage, the acute phase of the disease is usually overcome. If the infection is overcome quickly the amount of damage is minimal, and repair takes place rapidly. The super-

ficial layer of dead cartilage cells is exfoliated. The gaps in the synovial membrane are filled by the proliferation of endothelial cells and the joint is restored to a condition which approximates normal. If the infection has been severe, and particularly if it has been prolonged, the whole thickness of the articular cartilage may be destroyed, with resultant exposure of the

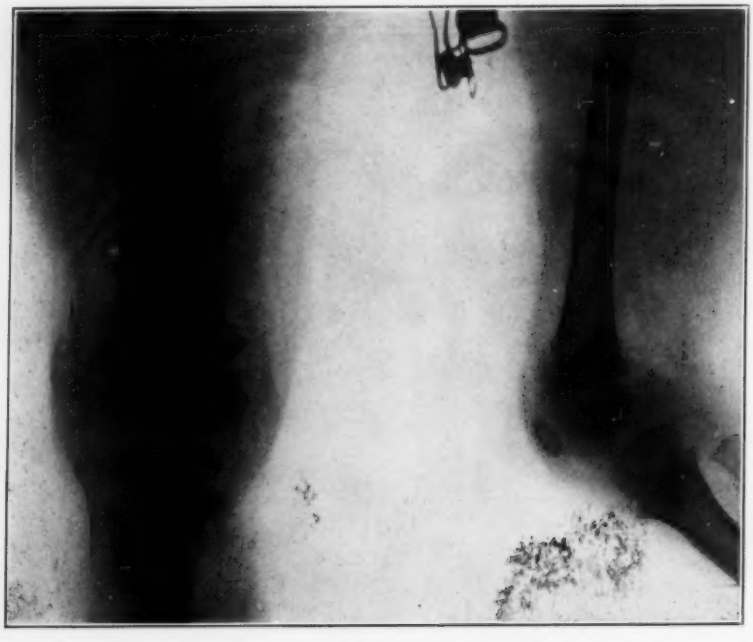

FIG. 3

Radiograph of knee two years after a severe arthritis due to colon bacillus. A normal range of movement was present. Roentgenogram shows slight irregularity of the articular surface of epiphysis, indicating that some destruction of articular cartilage had taken place. Crepitus was present on movement.

underlying bone. The place of the destroyed cartilage is taken by masses of granulation tissue or new bone, and these fusing with similar tissue on the opposite side of the joint, result in bony or fibrous ankylosis.

The amount of cartilage destroyed during the acute phase of the disease is of more importance than any other factor in determining the future function of the joint. If sufficient cartilage remains to permit gliding of the joint surfaces upon one another, the ultimate range of

movement will be considerable and may even approximate normal, no matter how severe the periarticular inflammation may have been. On the other hand, the destruction of cartilage and the formation of fibrous bands and mats within the joint results in ankylosis. In consequence of the dependence of future function upon the damage sustained by the articular cartilage, the majority of end results fall into two classes, viz., those who recover with a range of movement which is normal or approximately normal, and those who recover with ankylosed joints. The number who recover with movement of but a slight range is very small (4.4 per cent. in this series).

The damage which has been sustained by the joint during an acute arthritis is revealed by radiographs taken after the lapse of a considerable length of time. In those joints which have become ankylosed, whether the ankylosis be bony or fibrous, the roentgenogram (Fig. 2) shows gross destruction of the articular cartilage. In many cases osseous bridges cross the joint and produce a bony ankylosis. Even in those joints which recover movement, some irregularity of the articular surface is usually revealed by the roentgenogram (Fig. 3). This is paralleled by the nearly constant presence of crepitus on movement in such joints. It is quite possible that while the present condition of such recovered joints is very satisfactory, they will ultimately become the seat of an osteo-arthritis which will be more or less disabling.

SIGNS, SYMPTOMS, AND DIFFERENTIAL DIAGNOSIS

The signs and symptoms of acute suppurative arthritis in a superficial joint are sufficiently clear to offer no appreciable obstacle to diagnosis. The onset is abrupt, and in many cases is preceded by trauma. At an appreciable interval after the trauma, usually twelve or twenty-four hours, the joint becomes painful, swollen, and hot. Movement and weight-bearing are painful and quickly become impossible. Examination reveals muscle spasm, fluid within the joint capsule, and pain on the slightest movement. The joint is fixed, usually in flexion. The temperature is elevated from 100° to 103°, and a polymorphonuclear leucocytosis is present. Blood culture often demonstrates a septicaemia. In certain cases the source of the arthritis may be found in the immediate neighborhood of the involved joint, e.g., a penetrating wound or neighboring osteomyelitis. Finally, the obtaining of purulent fluid from the joint by aspiration completes the diagnosis.

In the deeply situated joints, diagnosis may be more difficult. This is particularly true in the case of the hip joint, where osteomyelitis of the

neck or of the upper end of the shaft of the femur or of the ischium may be indistinguishable from arthritis. The demonstration of pus within the joint by means of aspiration is the only certain diagnostic aid. In the case of the hip, aspiration should be undertaken from a point just in front of the great trochanter, the needle being directed inwards along the anterior surface of the neck of the femur until it enters the capsule.

In infants the diagnosis may be rendered difficult by the feebleness

FIG. 4

Radiographic findings one year after a streptococcal arthritis of hip joint, indicating that the arthritis had been secondary to an unsuspected osteomyelitis in the neck of the femur.

of their reaction to the infection since suppurative arthritis may exist without any elevation of temperature or leucocytosis. In such cases only the local signs of arthritis are present, and aspiration of the joint is the only certain means of diagnosis.

The conditions from which suppurative arthritis must be differentiated are inflammatory rheumatism and osteomyelitis. In the former the preceding history of tonsillitis, the multiplicity of the joints involved, and the comparative mildness of the inflammation usually indicate with

sufficient clearness the correct diagnosis. In the latter the point of greatest tenderness, swelling, and pain is over the epiphyseal line rather than the joint, and unless the joint has been secondarily involved there is movement without pain.

TREATMENT

The serious loss of function which may follow the damage caused to a joint by arthritis has led to a diversity of treatments, all having for their object the preservation of movement of the joint. Suppurative arthritis, like other suppurative foci, is cured most rapidly and effectively by free drainage. Unfortunately the complicated nature of the joint cavity in which the suppuration is occurring makes adequate drainage mechanically difficult, while the delicacy and importance of the structures operated upon during arthrotomy render dependent drainage practically unattainable without unjustifiable damage to the joint structures. The various modifications of treatment are, for the most part, attempts to obtain drainage without serious damage to the joint. They may be classified into three groups—1. Aspiration of the joint, with or without the introduction of antiseptics. 2. Arthrotomy and open drainage. 3. Arthrotomy and active movements of the joint.

Treatment by means of aspiration is an attempt to secure drainage of the suppurative focus with a minimum amount of damage to the joint structure. It is usually supplemented by the introduction of antiseptics (e. g., formalin and glycerin) or by various dyes (gentian violet, mercurochrome, etc.) whose action is thought to be selective upon the gram positive organisms which are the usual cause of septic arthritis. The drainage secured by such aspiration is very inadequate. Fibrin in large masses is nearly always present, and it prevents the removal of all the exudate by plugging the needle. At best the drainage secured is intermittent. Experience has proven it to be an unsatisfactory means of treatment. In most cases it does not overcome the infection, and in no case with the rapidity which is desirable in order to minimize the damage to the articular cartilage.

It cannot be emphasized too strongly that not only must the infection be overcome, but that it must be overcome quickly. The greater the length of time during which the purulent exudate lies in contact with the articular cartilage, the greater will be the damage to this structure and to the ultimate function of the joint. It is true that some infections of joints are so mild that aspiration can overcome them. There is, however, no certain criterion to distinguish this type of joint from any other, and the

delay involved produces unnecessary damage to the joint. Some more effective method of drainage which would damage the joint as little, is preferable to aspiration.

In our experience the introduction of antiseptics or dyes following aspiration has not been of value. The reaction to formalin and glycerin

FIG. 5

Range of flexion and extension after a staphylococcal arthritis of right hip. Treatment: anterior arthrotomy; drain to capsule; extension with pulley and weights.

is severe, and there must be a considerable amount of damage to the tissues within the joint. The various dyes which have an affinity for gram positive organisms do not seem to exercise a selective bactericidal action upon them.

Treatment of suppurative arthritis by arthrotomy provides more adequate drainage, and if appropriate precautions are exercised, the joint

may be opened in such a manner as to cause little if any permanent damage. This method is much to be preferred to aspiration. Extensive operations upon the joint with the object of securing perfect drainage should not be undertaken. While they may secure excellent drainage, the amount of operative damage suffered by the joint is too great to justify the procedure. In the great majority of cases satisfactory drainage can be secured by simple linear or cruciate incision of the capsule. The capsule should be approached in its most accessible part, and with a minimum amount of trauma to the periarticular structures. The incision into the capsule should be as large as the exposure will permit. No drains should be placed within the joint, as their presence is a source of damage to intraarticular structures. In the deeply situated joints a drain should be placed through the overlying soft tissues down to the incision in the capsule.

Dependent incisions in the capsule are not essential, and since in many joints they cannot be made without unjustifiable damage to the joint structure they are undesirable. In the knee, incisions through the capsule on either side of the patella provide drainage with negligible permanent damage to the joint. In the hip, the joint may be approached with equal facility from in front or behind. As far as the ultimate result is concerned it does not appear to make much difference which approach is used. The anterior incision (of the hip) is somewhat easier to care for, and this is a point worth considering in joints which are extremely painful on movement.

While the drainage secured by simple incision of the capsule in its most accessible part may not be theoretically ideal, experience has amply proven that it is adequate for the cure of the infection. It has the additional great advantage that no irreparable damage is done to the joint structures. Once the infection is overcome, the incision in the capsule heals and perfect recovery of movement can take place, provided the articular surfaces have not been injured by the infection.

Treatment of suppurative arthritis by arthrotomy supplemented by active movements, as first instituted by Willems, is inapplicable to children, since it is impossible to secure from them sufficient co-operation. Any value it possesses over simple arthrotomy must lie in improvement in drainage. Contraction of the muscles controlling the joint tenses the capsule and expresses pus from pockets which are not readily emptied by any other means. It has, however, the great disadvantage that it results in increased pressure upon and friction between the articular cartilages, which are already damaged by the infective process. This cannot fail to increase the destruction of the cartilage, and therefore the probability of permanent damage to the joint. It would, moreover, seem contrary to

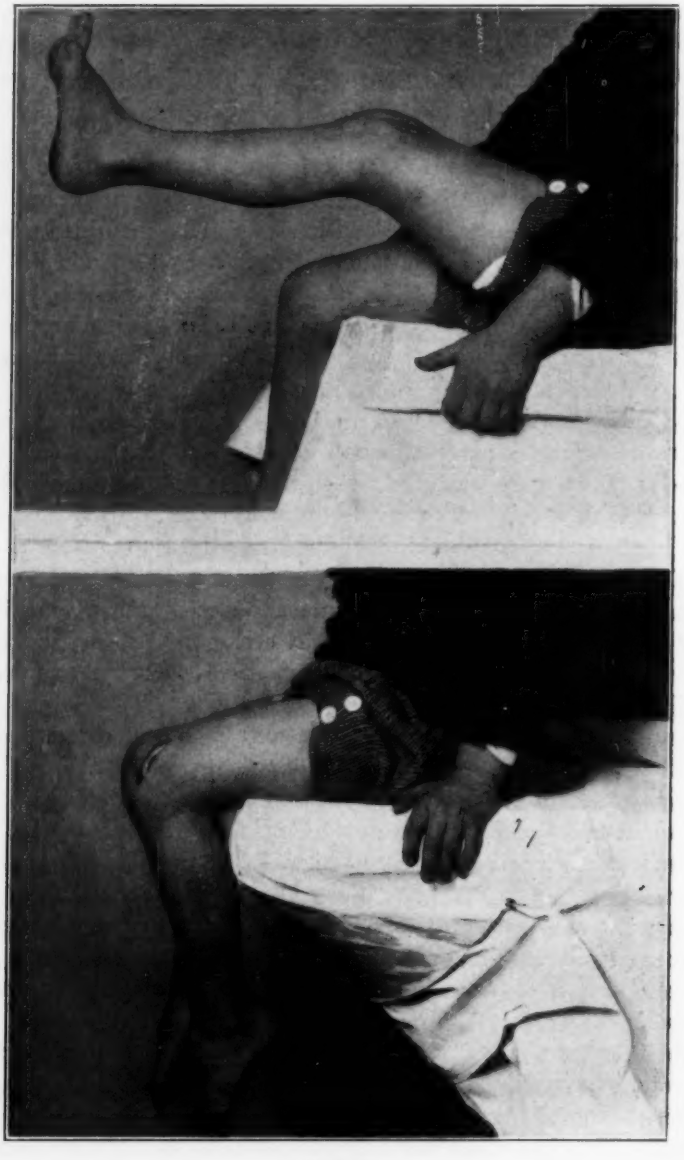

FIG. 6[a]

Range of flexion and extension ten weeks after a staphylococcal arthritis of knee. Treatment: bilateral anterior arthrotomy on either side of patella; fixation in Thomas splint, and extension.

all principles of treatment to insist upon the movement of acutely painful joints.

It is important that treatment be instituted early, since the longer the cartilage remains in contact with the purulent exudate the greater will be its destruction. The infection too, is more easily overcome in its early stages than when it has established a firm foothold in the whole of the joint. If the clinical symptoms indicate a suppurative arthritis, but the aspirate removed from the joint shows no organisms on direct smear, it is wiser to open the joint at once rather than to wait for results of culture. No permanent damage can result from the simple arthrotomy described, while much damage may result from the continued presence of pus within the joint, because of its digestive action upon the articular cartilage.

The treatment instituted for the suppurative arthritis should be supplemented by fixation and extension. This prevents the occurrence of deformity and relieves the patient of pain, his most distressing symptom. In addition the articular surfaces are spared the additional trauma resulting from movement and pressure, and their destruction is therefore minimized. The fixation and extension should be retained only during the acute phase of the disease. As soon as the infection has subsided they should be discarded for short but increasing lengths of time until in the course of one or two weeks they can be removed entirely.

PROGNOSIS

Mortality:

Since many cases of suppurative arthritis occurring in children are the result of a septicaemia, the mortality is considerable. In this series it amounted to 12.3 per cent. The mortality is highest among infants, whose resistance against septicaemic infection is never high and often is still further lowered by complicating respiratory disease or malnutrition due to improper feeding. In such patients wide-spread localizations of the septicaemia, such as peritonitis, empyema, pericarditis, and septic pneumonia, are prone to occur, the arthritis being but an incident in a widely disseminated infection. Infants die from the septicaemia rather than from the arthritis. Older children show a better resistance to septicaemia, though here also overwhelming infections may be fatal in a short time.

Function:

In those patients who recover, the outlook as to function is primarily dependent upon the amount of destruction of articular cartilage which has taken place. It is damage to this structure, rather than to synovial

membrane and capsule, which determines ankylosis and limitation of movement. The degree of destruction of the articular cartilage which will take place in any case of arthritis is dependent upon many factors, the chief of which are: the nature of the infecting organism, the mode of invasion of the joint, the nature of the treatment, and the stage at which treatment is instituted.

The staphylococcal infections are the most virulent and destructive, as well as the most frequent. Once established in a joint they have a greater power of absorbing the articular cartilage and thus producing permanent damage, than have any other organisms. Unless drainage is established early, staphylococcal infections are almost certain to produce some degree of permanent impairment of joint function.

The streptococcal infections are somewhat less destructive than the staphylococcal, but apart from this difference in degree their action is similar. The virulence of streptococcal infections varies greatly in individual cases, much more so than the staphylococcal cases.

Infections caused by pneumococci, influenza bacilli, and colon bacilli are much less destructive than those caused by staphylococci and streptococci. Recovery of movement, even when drainage has been delayed, is not unusual.

The manner in which the organisms have reached the joint is of some importance in determining the ultimate result. Those cases in which the joint has been infected from without, as by a penetrating wound, or from a neighboring focus, as from osteomyelitis, are more prone to permanent loss of function than are those joints which are infected from the blood stream. This might be anticipated, particularly in the osteomyelitic cases, since in them there exists in the immediate neighborhood an ineradicable source of organisms from which the joint is continuously reinfected. The joint infection cannot be overcome completely until such time as the bone infection is adequately drained, and this may be difficult and require time. On the other hand, in the septicaemic cases, if the patient overcomes the blood stream infection, the joint condition remains as an isolated focus to be dealt with by itself.

The nature of the infecting organism and the path by which the joint is invaded are factors influencing ultimate function which are beyond the control of the surgeon. On the other hand, the nature of the treatment and the time at which it is instituted are controllable factors and ones which exert a profound influence upon the end result, as indicated in the section on treatment. Treatment by aspiration is not productive of the best results. A few of the milder cases may be cured by this means,

but there is no certain method of ascertaining such cases, and the time lost by trial of this method is dangerous. The injection of antiseptics and dyes is not of value. The sole advantage of treatment by aspiration, viz., minimum operative damage to the joint structure, is equally well obtained by simple arthrotomy. If this is limited to mere incision of the capsule in its most accessible point, without the introduction of drains into the joint, no permanent damage occurs, while greatly improved drainage is obtained. The adequacy of the drainage is indicated by the rapid fall in temperature after the operation, together with the subsidence of the local signs of inflammation.

The value of supplementary active movements is debatable. In many cases, including all those occurring in children, it is inapplicable because of failure in co-operation. In many cases it is unnecessary. Against any advantages is to be weighed the increased damage to the articular cartilage due to increased pressure and friction.

There exists a relationship between the length of time the arthritis has existed without drainage and the amount of damage which the articular cartilage suffers. The longer the purulent exudate remains in contact with the articular cartilage, the greater will be the damage to the joint. Drainage should therefore be instituted early. If the clinical signs are those of arthritis, and if diagnostic puncture reveals pus, it is better to open the joint at once than to wait for cultural examination of the aspirate. The time gained is of more importance than the danger of opening a joint which is not frankly suppurating.

REPORT OF CASES

Material:

The cases of suppurative arthritis forming the basis of this thesis consist of those admitted to the Hospital for Sick Children, Toronto, during the six years from October, 1918, to October, 1924. Only those cases are included in which the patient was admitted during the acute stage of the disease, and in which examination at a late stage has permitted an accurate estimate of the permanent function of the joint. These comprise fifty-one cases of suppurative arthritis occurring in forty-nine patients. Six of the patients died (all having involvement of one joint only). There remain available for the study of end results forty-five joints occurring in forty-three patients.

Mortality:

The mortality was 12.3 per cent. (six deaths amongst forty-nine patients). Four of the deaths occurred in malnourished infants under

eighteen months of age. In all four of these cases death occurred from such complications of the septicaemia as peritonitis, empyema, septic pneumonia, and meningitis. The remaining two deaths occurred in older children (eight and twelve years). In one case death occurred in forty-eight hours from the onset as the result of a fulminating staphylococcal septicaemia with such wide-spread local manifestations as septic pneumonia, osteomyelitis, empyema, and multiple abscesses in the kidney, as well as arthritis of the hip. The arthritis was but an incident in a most wide-spread and virulent infection. In the other case death occurred from a respiratory complication of uncertain nature within a few hours of operation upon the joint,—the only operative death in the series.

ETIOLOGY:

In five cases (9.8 per cent., Table I) the joint was directly infected by means of a penetrating wound. In every case the involved joint was the knee, and the accident resulted from a fall upon some sharp object, such as a nail or a thorn.

	Penetrating wound of joint	*Extension from neighboring focus of infection*	*Haematogenous in origin*
Knee.....	5	7	15
Hip.....		3	15
Ankle.....		3	1
Elbow.....		1	
Shoulder.....			1
	5 (9.8%)	14 (27.4%)	32 (62.8%)

TABLE I—Path of invasion of Joint.

In 14 cases (27.4 per cent.) the joint was invaded from a neighboring septic focus. In all but one case the focus from which the infection arose was osteomyelitis in one of the bones entering into the formation of the joint. This occurred six times in the knee, three times in the hip, three times in the ankle, and once in the elbow. The remaining exception was an infection of the knee arising by extension from a prepatellar bursitis.

In thirty-two cases (62.8 per cent.) the arthritis was haematogenous in origin. In thirteen of these cases (41 per cent.) the onset was preceded by a definite history of trauma. In most of the cases organisms were demonstrated in the blood stream. In seventeen of the cases (53.1 per cent.) the primary focus giving rise to the septicaemia was found. Table II indicates the nature of the primary foci and incidence of the various organisms in each.

Trauma		*Primary Focus*	
Present	*Absent*	*Found*	*Not Found*
13 (41%)	19 (59%)	17 (53.1%)	15 (46.9%)

32 Cases

Analysis of primary foci producing septicaemia

	Haem. Strep.	*Staph.*	*Bac. Col.*	*Inf. Bac.*	*Total*
Infected Skin Lesions	2	4			6
Otitis Media	5				5
Nasopharyngitis	1				1
Cervical Adenitis	1				1
Pyelitis			1		1
Cellulitis of Orbit				1	1
Scarlet Fever	1				1
Infected Haematoma	1				1
	11	4	1	1	17

TABLE II—Incidence of trauma and demonstrable primary focus in haematogenous cases and analysis of primary foci found.

CAUSATIVE ORGANISMS (TABLE III):

The most frequently found organism was the staphylococcus, which was present in 47 per cent. of the cases. It was the only infecting organism found in the cases arising by extension from an osteomyelitis, occurred once among the cases caused by penetrating wounds, and twelve times among the haematogenous cases.

	Penetrating wound	*Extension from neighboring septic focus*	*Haematogenous*	*Total*
Staph. Aureus	1	11	12	24 (47%)
Haem. Strep.	2	1	12	15 (29.4)
Sterile	2	2	1	5 (9.8)
Unidentified			3	3 (5.9)
Infl. Bac.			2	2 (3.9)
Pneumococcus			1	1 (2.)
Bac. Coli			1	1 (2)
	5	14	32	51 (100%)

TABLE III—Incidence of organisms in suppurative arthritis and their relationship to the various paths of invasion.

Streptococci, always of the haemolytic variety, were the causative organisms in fifteen cases (29.4 per cent.). They occurred in two of the

cases of penetrating wounds, in one case in which the joint was invaded from a suppurating prepatellar bursitis and in twelve of the haematogenous cases.

Influenza bacilli occurred in two cases, both haematogenous in origin. Pneumococci and colon bacilli were each present in one case, both also haematogenous in origin.

In eight cases the record of the culture was lost or the organism was not identified. In five cases the culture was sterile. In one case the failure to grow was apparently due to extreme attenuation of the organisms, as they were found on direct smear, but could not be grown on culture. In another case failure to grow was apparently due to some unusual type of organism. The infection was subacute but gave rise to great quantities of pus. It led to extensive joint destruction and ultimately to complete ankylosis of the joint. Repeated cultures were sterile and guinea pig inoculation ruled out tubercle bacilli.

Pathological Findings:

Observations made at operation and post mortem examination revealed the changes of the early stage to be congestion of the synovial membrane and fibrino-purulent exudate within the joint. If the condition had existed for more than a few days, the articular surface was found to be eroded, the erosion being greatest at the margins of the articular surfaces where the greatly swollen synovial membrane overlay the cartilage. In the worst cases erosion of the cartilage had progressed until the underlying bone was exposed and the gap filled with granulation tissue. When gross destruction of the cartilage had taken place the joint was filled with a mass of granulation tissue.

Roentgenograms of the surviving patients taken one or more years after the acute illness revealed, in the ankylosed cases, great destruction of the articular surfaces, and often fusion of the ends of the bones by masses of new bone. In those cases which recovered with movement the changes in the epiphysis were slight, though usually present. There were no evidences of damage due to the operative scar.

Treatment Adopted:

The great majority of cases were treated by simple arthrotomy, plus fixation and extension. The usual procedure was to perform an arthrotomy as soon as possible after the diagnosis had been made, approaching the joint from its most accessible point and opening the capsule with as large a linear or cruciate incision as was feasible. In the more deeply situated joints (such as the hip) a drain was inserted through the soft

tissues down to the capsular incision but not into the joint. In other joints (e.g., the knee) drains were not used. In the majority of cases the incision was not in a dependent part of the capsule, since to have placed it there would have involved more damage to periarticular structures. In the knee, bilateral anterior incisions on either side of the patella were used. In the hip, a cruciate incision in the anterior or posterior surface of the capsule, either approach being equally good. Moist dressings were applied and maintained until the discharge from the joint had ceased. Neither active nor passive movements were used as an essential part of the treatment. Fixation by means of some type of splint was used in nearly every case (Thomas splint for the knee and plaster for the arm), the position of fixation being that which would be most useful should ankylosis occur. In the lower limbs sufficient extension was applied to overcome muscle spasm. Fixation and extension were maintained until the signs of acute inflammation had subsided, usually ten days or two weeks, but sometimes sooner. After this time the extension was discarded entirely. At the same time the splint was left off for a part of each day, during which time the patient was allowed and encouraged to move the joint. Since pain had disappeared when this stage was reached, there was little difficulty in securing movement. The time during which the splint was discarded was increased rapidly until it was worn only at night, in order to prevent recurrence of the deformity. When the wound had healed the patient was allowed up.

The above treatment was used in such a large majority of the cases that the results obtained may fairly be regarded as a criterion of its value.

In a few cases treatment by means of aspiration was carried out. In some of these cases the arthritis was mild and subsided so rapidly under a single aspiration as to render it apparently unnecessary to resort to further measures. In other cases the hope was entertained that by supplementing aspiration with the injection of antiseptics (formalin in glycerin) or dyes (gentian violet) the infection might be overcome more rapidly. All these cases were failures and ended in ankylosis. There were in all eight cases treated by aspiration. Of these, three recovered with full movement, but in two of these the culture was sterile and in the third an unidentified gram negative organism grew slowly in the culture media. The remaining five cases all ended in ankylosis.

RESULTS OF TREATMENT:

Among the forty-three patients who survived the infection there were forty-five joints which had been the site of a suppurative arthritis and

which therefore are available for examination of the ultimate function of the joint. Of these, irrespective of the manner in which they were treated, twenty-two recovered with a normal range of movement, four recovered with a range of movement between two-thirds and full normal, two recovered with a small range of movement (about one-quarter normal) and seventeen ended with bony or fibrous ankylosis. The results may be summarized as follows:

Normal or approximately normal range of movement	57.8%
Small range of movement or ankylosis	42.2%
	100%

The results obtained by the two types of treatment used, viz., aspiration and arthrotomy, are indicated in Table IV. It shows the advantages of arthrotomy over aspiration, in spite of the fact that among the latter were grouped some of the mildest forms occurring in the series.

	Recovery with normal range of movement	*Recovery with Ankylosis*
Aspiration	3 (37.5%)	5 (62.5%)
Arthrotomy, Fixation and Extension	23 (62.2%)	14 (37.8%)
	26	19
	45 Cases	

TABLE IV—Summary of results obtained by various forms of treatment.

NOTE: For the sake of convenience, in this table those cases (four in number) in which the range of recovered movement was large but not quite full, have been grouped as complete recoveries, and those cases (two in number) in which the recovered movement was small, with the cases of ankylosis.

The influence of the various causative organisms upon the ultimate result is indicated in Table V. It shows the increased power of destruction possessed by staphylococci and streptococci; the recovery rates for these two organisms being 47.4 per cent. and 58.3 per cent. respectively. While the figures for the remaining organisms are of little value because of the small number of cases represented, they do indicate a very much diminished virulence as compared with streptococci and particularly staphylococci.

	Recovery with normal range of movement	*Recovery with Ankylosis*
Staphylococci	9 (47.4%)	12
Streptococci	7 (58.3%)	5
Sterile	4 (80%)	1
Unidentified	2 (66.6%)	1
Inf. Bac.	2 (100%)	
Pneumococcus	1 (100%)	
Bac. Coli	1 (100%)	
	26	19

45 Cases

TABLE V—Summary of results grouped according to the causative organisms.

Examination of the cases with reference to the path of invasion of the joint as indicated in Table VI, shows the greater destructiveness and persistence of arthritis arising from infection by penetrating wounds and extension from neighboring septic foci, than the haematogenous infections. The recovery rates were: following penetrating wounds, 40 per cent.; following invasion from neighboring septic foci, 42.9 per cent.; following haematogenous infections, 69 per cent.

Path of Invasion of Joint	*Recovery with normal range of movement*	*Recovery with Ankylosis*
Penetrating Wound	2 (40%)	3 (60%)
Invasion from neighboring septic foci	6 (42.9%)	8 (57.1%)
Haematogenous	18 (69%)	8 (31%)
	26	19

45 Cases

TABLE VI—Summary of results grouped according to path of invasion of the joint.

The majority of the cases were admitted only after the disease had been present for several days. There is little material, therefore, which would indicate the value of early operation. Table VII does show, however, that among ten cases operated upon on the fourth day or earlier, there were only two in which ankylosis occurred. There were twenty-three cases operated upon on the fifth day or later, and of these fifteen became ankylosed.

Day on which treatment was started	*Staphylococcus*		*Streptococcus*	
	Recovery	*Ankylosis*	*Recovery*	*Ankylosis*
1st	1			
2nd	1	1	2	1
3rd	1		2	
4th	1			
5th or later	5	11	3	4
	9	12	7	5

TABLE VII—Summary of results in the staphylococcal and streptococcal cases grouped according to the day of the disease on which treatment was commenced.

SUMMARY AND CONCLUSIONS

1. An analysis is presented of the etiology, treatment, and end-results of 51 cases of suppurative arthritis.

2. The best treatment is simple arthrotomy for drainage, instituted at the earliest possible moment and supplemented with fixation and extension.

3. Such treatment results in recovery with normal movement in more than half of the cases.

DAVIS METHOD FOR CLOSED REDUCTION OF CONGENITAL DISLOCATION OF THE HIP

BY FRANK D. DICKSON, M.D., KANSAS CITY, MO.

A number of methods have been devised for the reduction of congenital dislocation of the hip by manipulation. All of these have been successful in the hands of those who have employed them as a routine. The Davis procedure is one of these methods which has been used by a limited group of men, but has not been widely adopted. This, it is felt, is due to a lack of understanding of the manner in which the reduction is made, as the method is simple and efficient. It seems worth while, therefore, to call attention again to a procedure which may well find a useful place in the armamentarium of the orthopaedic surgeon in the treatment of congenital dislocation of the hip.

There are in general two methods of replacing a dislocated joint: the direct method and the indirect or circumduction method.

In the direct method, the dislocated bone end is put in the most favorable position for reduction and then lifted or pulled into place. The extension method of Bradford and Mickulicz, and possibly the method of Hibbs, may be considered as applying the direct method of reduction to congenital dislocation of the hip.

In the indirect or circumduction method, leverage is used for making the reduction. The extremity is used as the lever, the ligaments as the fulcrum and the dislocated head is rotated into place. Paci of Bologna in 1894, and Lorenz a year later, popularized the circumduction method of reduction as applied to congenital dislocation of the hip.

In the year 1903, Dr. G. G. Davis of Philadelphia described a method for reduction of congenital dislocation of the hip, which he named the Push Method. It may be considered to be a combination of the direct and circumduction methods, as both are employed in its technique. This method was successfully used by Dr. Davis for a number of years and is now the routine method used in reducing congenital dislocation of the hip at the Hospital of the University of Pennsylvania, the Orthopaedic Hospital, and several other Philadelphia hospitals. It has been used by myself in a large number of cases for the past fifteen years.

The present report is of twenty cases, including twenty-four dislocated

hips reduced by this method, of which complete records are available. In a number of other cases this method has been used, but as the records are not complete or the cases still under treatment, they are not considered in reporting this group.

FIG. 1

The child is placed in a prone position on a well padded table.

Fig. 2

The hip on the affected side is acutely flexed with knee bent until the knee lies against the side of the chest. Note elevation of perineum from table.

The method described by Dr. Davis may be divided into the following steps:

(1) The child, in anaesthesia, is placed in a prone position on a well-padded table. (Figure 1.)

(2) The hip on the affected side is acutely flexed with the knee

bent until the knee lies against the side of the chest in a position of acute axillary flexion. (Figure 2.) This brings the head from a high position on the dorsum of the ilium to a low position.

(3) With the knee held firmly against the side of the chest, downward thrusts are made on the trochanter with the heel of the hand. (Figure 3.) This stretches the adductors. As the adductors stretch, the perineum, which is elevated when the thigh is flexed, approaches the table and when all has been gained in this way that is possible, the doubled-up fist of an assistant is placed under the knee, thus raising the perineum sufficiently to permit further stretching. (Figure 4.) As this stretching proceeds, the head slips from the posterior plane of the pelvis onto the anterior plane.

FIG. 3

With the knee held against the chest downward thrusts are made on the trochanter with the heel of the hand.

The best indications that this has occurred are the following: (1) Feeling the head slip forward; (2) Noting when the knee lies definitely dorsal to the plane of the hip joint (Figure 4); (3) Feeling the forward movement of the head with the fingers of the unengaged hand placed in the groin.

(4) With the head on the anterior plane, the hip is gradually brought from the position of acute axillary flexion to a position of a right angle flexion (Figure 5) by a "pump handle" movement, firm pressure being maintained on the trochanter with the heel of the hand while this manoeuvre is carried out. As the thigh approaches a right angle position, the head slips upward into the acetabulum. Dr. Davis always stated that it slipped up through the cotyloid notch and it is our opinion that this does occur.

FIG. 4

The doubled fist of the assistant is placed under the knee allowing greater stretching of the adductors and firmer thrusts on the trochanter. Knee lies dorsal to plane of hip-joint, indicating head has passed onto the anterior plane.

FIG. 5

The leg is brought down by "pump handle" movements, the head slipping into the acetabulum.

The hip or hips are then placed in plaster in a right angled position or as near this position as the stability of the reduction will permit. (Figure 6.)

Throughout the procedure little force and no violence is used. No leverage action is necessary, the force being applied directly to the upper end of the femur. If the thigh is held closely applied to the chest wall until the head slips forward, there is no possibility of causing a fracture or epiphyseal separation. The stretching of the adductors is accomplished gradually and with little trauma, so that there is never any reaction of any

FIG. 6

The hip is then dressed in plaster in right angle position.

consequence. In fact, the child suffers so little from the procedure, that it is our practice to allow the child to be taken home the day after the reduction.

The after treatment as carried out by us, since Dr. Adams has brought to our notice the post-operative treatment of Denucé, has been to allow the original plaster dressing to remain on for about six months without changing, if possible. If the cast is changed during this time, the hip is put back in the same position of right angle flexion. At the end of six months, a bivalve plaster dressing is applied, from which the child is

carefully removed each day for exercises. The exercises first given are flexion and extension of the hip with the thigh held in a fully abducted position, the child lying on a hard table on its abdomen so that adduction is impossible. After two weeks another exercise is added; the child is placed on its abdomen and taught to raise the still flexed and abducted limb from the table. By this exercise we hope to still further stretch the adductors and strengthen the gluteal muscles, which should make for stability of the hip joint. After a month of such exercise, the child is allowed to go without the plaster dressing during the day, and movement in all directions is permitted, but the cast is reapplied at night. The child is not allowed to stand and walk for another two to four weeks. The cast is then discarded and the child allowed to do what it will, walking is encouraged, and normal use of the hip resumed as rapidly as possible.

Of the twenty cases here reported, reduced by this method, the following facts are submitted:

AGE: the youngest child was 2½ years, the oldest 17 years, with an average age of 4½ years. It should be stated that the child 17 years old was a very small, undeveloped girl, and the hips were reduced with very little difficulty, it being a bilateral case.

HIP AFFECTED: four of the twenty cases were double, and sixteen were unilateral. Of the unilateral, thirteen were of the left hip and three of the right.

SEX: all the double dislocations were females. Of the unilateral cases, four were males and twelve were females.

In three of the twenty cases, all unilateral, it was impossible to reduce the dislocation, and open operation was resorted to. In one of these, a girl aged three years, an hour-glass contracture of the capsule was found, with an opening so small that it would have been impossible to have pushed the head through it. In the other two cases, aged 8 and 9, practically no neck was present, and the head was rudimentary, being merely a smooth surface upon the upper end of the femur. We feel that this accounts for the failure to secure reduction in these cases. It should be stated that in these three cases, previous attempts had been made to reduce the hips by other manipulative methods without success.

The remaining seventeen cases, including twenty-one dislocated hips, were successfully reduced. Eighteen of these had excellent results, both anatomically and functionally. In one case, a child 2½ years old with a double dislocation of the hip, the left hip has remained in place and is normal in appearance. The right hip, however, has from the first shown extreme anteversion of the neck. The hip was carefully observed, and

after two years showed marked indications that a redislocation would occur in time as the anteverted head was apparently not firm in the acetabulum, the roof of which was steadily becoming more sloping in form. An osteotomy was done to correct the anteversion and has resulted in a much better gait and apparently a much more stable hip. It is too soon to determine the final outcome.

FIG. 7

Roentgenogram showing anteversion of the neck, with sloping acetabular roof on both sides. Right hip partly redislocated. (See text.)

A second hip, (the patient three years of age), a right unilateral dislocation, was reduced and had from the start marked anteversion of the head of the femur. This patient was not seen for almost two years, but returned recently with a partly dislocated right hip. The roentgenogram (Figure 7) showed marked anteversion of the neck on both sides and also a markedly sloping acetabular roof on both sides. In this case, osteotomy to correct anteversion was recommended, both for the dislocated hip and the apparently normal hip, as it was feared a complete reluxation on the

right side would occur and because of the possibility of a late dislocation on the left side.

Our experience has been that in the younger children, that is, from 2½ to 4 years, very little difficulty is experienced in making the reduction, as in only one out of fifteen within these age limits was it impossible. We have had no difficulty in maintaining the reduction when secured. Also at this time we feel there is less anteversion of the head present, and that once reduced, there is less possibility of a redislocation occurring. For this reason, we believe that the earlier a congenital hip is reduced after two years of age, the better. Careful instruction of the mother is the best way to care for the child in a plaster dressing and makes it possible to treat young children quite successfully.

In the bilateral case of the girl aged 17 years, after the removal of the plaster dressing, both hips were found markedly limited in motion. The left hip has persistently remained in this condition, and when last seen, several years ago, was almost completely ankylosed. In another patient, aged 7 years, many months of after treatment were necessary to restore normal motion in the hip, a difficulty which we have never had in the young cases. This complication was experienced in several other patients, 7 years of age and older, not included in this series. We feel, then, that in the older patients, 7 years and up, the difficulties of reduction are greater, the possibility of persistent deformity is more likely, and the danger of stiffness in the joint must be feared more than is the case with younger children, and as a result the chances for a successful outcome are distinctly less.

The results in twenty-four hips reduced by the Davis method were: twenty-one out of the twenty-four hips were reduced, giving a percentage of 87.5 successful reduction. Of the twenty-one hips reduced, in three the results have not been satisfactory, giving a percentage of 85.7 good results. We feel that these results as to reduction and outcome compare favorably with those of other methods of closed reduction.

As a result of my experience with the Davis method of closed reduction of congenital dislocation of the hip, I feel that the following conclusions may be drawn. (1) That the Davis method is as effective in its results as any of the accepted methods; (2) As the force is applied to the head of the bone, no leverage action being used, there is less danger of producing a fracture of the femur than in most of the circumduction methods; (3) There is a minimum amount of trauma to the soft parts by this method, which is a very desirable factor, little or no reaction following; (4) The sooner after the age of two years the hip or hips are reduced, the better the results;

(5) The closed reduction after the age of seven years is difficult and the outcome as a rule far from satisfactory.

DISCUSSION

Dr. Z. B. Adams, Boston: I want to thank Dr. Dickson for this excellent presentation. With the motion picture he has given us an idea of the Davis method. Those of you who were fortunate enough to see Dr. Davis' work or see the hips he reduced are familiar with it. I had an opportunity of seeing him reduce a hip years ago and I think all of you will agree with me that whatever Dr. Davis did in orthopaedic surgery was thoroughly worked out anatomically. I think this is a very excellent example of one of Dr. Davis' contributions to orthopaedic surgery.

Dr. John Ridlon, Chicago: There is really nothing to say about this. I had an opportunity of seeing Dr. Davis do this operation in the early part of this century and Dr. Dickson does it even better than Dr. Davis did it. There is no doubt that one familiar with this manipulation can put one of these hips in more easily than he can by a manipulation with which he is not familiar. After Dr. Dickson was in Chicago and presented this subject during the winter I tried the method in the next case that Dr. Berkheiser had at the Home for Crippled Children. I endeavored to carry out the method exactly as shown in these pictures. I used all the force that I dared to use and I could not get the hip in. It was probably because I did not do it right, because Dr. Dickson seemed to do the work so easily. I tried that and I tried also to find out whether I could keep in my fingers of the other hand the relation of the head to the acetabulum as he had in the method which he advised. I did not find that I could do that. It seemed to me then and now after seeing these pictures that the same criticism of this operation is justified as of the Denucé operation, and as far as I know of all the other operations except my own, — that is, one tries to put the head in without any conscious knowledge of the relation of the head to the acetabulum step by step during the manipulation, which is easy to do by my method. That is the only criticism. Of course, the final results, the percentage of cures by this method, should be just the same as by any other method.

Dr. John L. Porter, Evanston, Ill.: I would like to ask Dr. Dickson if he finds when he cuts the cast that the head has moved across the acetabulum and is transposed anteriorly as one sees in other methods of manipulation.

Dr. J. T. Rugh, Philadelphia, Pa.: The point that has always impressed me most strongly in the reduction of these cases of congenital dislocation is the amount of traumatism that is inflicted on the head which nature has never completely formed or which has been imperfectly developed. I had the privilege of being taught the method by Dr. Davis, and at my request in several cases where I was unable to reduce the dislocation, he reduced it for me by this plan. I have been impressed with the amount of traumatism that is possible in cases of this kind as compared with the traumatism concerned with the manipulation in the method of Ridlon and perhaps that of Denucé. I feel that I do not have as good control of the hip joint and that I can not prevent injury to the sensitive head, and *that* I think is absolutely essential in these cases of congenital dislocation. I recently saw some cases in a neighboring State where one of the surgeons discussed the reduction of these cases and the operative procedures that

were followed in the replacement. I asked the surgeon what was the result of his manipulations ten, twelve, or fifteen years afterwards in these heads which were imperfectly formed. He said, "I am not concerned with that." I am concerned with it, and it is the concern of every orthopaedic surgeon as to the amount of damage that is inflicted on these heads. There are many of these cases in which the Davis method is a splendid method of reduction, but I think there is that fine distinction in the amount of traumatism inflicted on these heads which we must take into consideration.

Dr. Frank D. Dickson, Kansas City, Mo. (closing the discussion): The chief point which the discussion seems to have brought out is the question of traumatism. We think there is much less trauma in the Davis method than in any other. I have never seen any bad results following the cases in Philadelphia, and as I said to Dr. Ridlon in Chicago, I have never seen a fracture, epiphyseal separation, or any damage. Dr. Ridlon very kindly told me that he did not consider there was any more trauma than with his method. We let these patients go out of the hospital the next day. In my opinion there is much less traumatism to the soft parts and much less general traumatism. I think the traumatism is more imaginary than real.

Dr. Ridlon says the results are about the same. In this small series of cases, and they are the only ones in which we have complete data, the successful reductions were 87.5 per cent. and the successful outcomes, both anatomical and functional, were 85 per cent., which I think compares favorably with those secured by other methods. The age of the patients varied from two and one-half to seventeen years, the average age being about five years. The seventeen-year old patient was a very much underdeveloped girl and the result was very unsatisfactory. She had an ankylosis in the left hip. I believe the earlier the reductions are done the better. I believe in a child with a dislocated hip two years of age is the right time to operate. I cannot agree with Dr. Rugh in regard to the trauma.

THE X-RAY TREATMENT OF CALLOSITAS AND VERRUCA PLANTARIS WITH SOME REMARKS ON THE PATHOGENESIS OF THESE LESIONS*

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C. LEE McCARTHY, M.D., WASHINGTON, D.C.

Calluses and warts occurring upon the plantar surface of the feet cause the orthopaedic surgeon and many times the dermatologist endless trouble. From the point of view of the patient the pain arising from these two lesions may be severe enough to prevent him from performing his daily duties.

It is intended to discuss these conditions briefly with reference to their clinical, pathologic, and therapeutic sides. Unfortunately the roentgen ray treatment of these two conditions has not been given the attention it rightly deserves; frequently we hear of the excision of calluses or warts without recourse to X-rays. It is true that occasionally it may be necessary to excise calluses when mechanical appliances, salicylic acid, plasters, and X-rays have failed. We desire to preface our remarks by saying that whenever possible the opinion of an orthopaedic surgeon should be sought regarding mechanical appliances, proper posture, etc., for only with his aid are we able to cure the large majority of these cases and to prevent recurrence.

PATHOLOGY. A callus is simply an exaggerated hypertrophy of the horny layer over circumscribed areas which have been subjected to pressure or irritation. (Fig. 1.) Normally the corneous cells become dry and flake off. In the formation of a callus the corneous cells become adherent, heaping themselves up into a mass of keratotic tissue. The origin of this hypertrophy of the stratum corneum is not well understood; it is probably ushered in by some injury in the derma which sets up an inflammatory reaction and in due time causes a hyperplasia of the epithelial cells. (Fig. 2.) The pressure from without causes the corneous cells to become more keratotic, compressed more firmly, and in some instances their consistency

*From the service of Dr. F. H. Dillingham, Dept. of Dermatology, and the service of Dr. A. J. Quimby, Dept. of Roentgenology, New York Polyclinic Medical School and Hospital.

FIG. 1a

This patient presented callus over all the heads of the metatarsals.

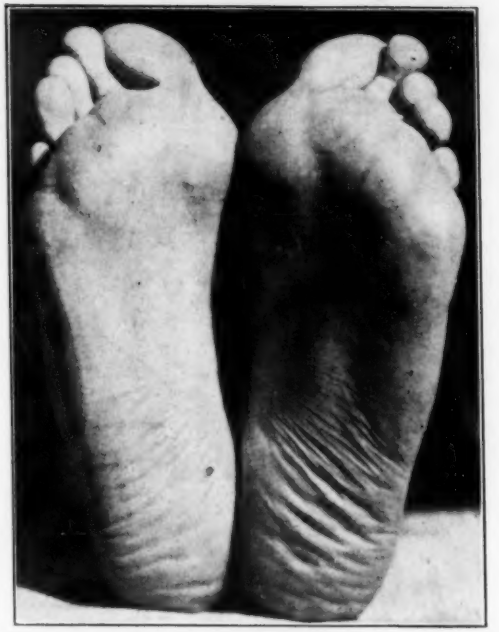

FIG. 1b

After two X-ray treatments (H 1½ each treatment) callus cleared up entirely.

resembles bone. In time the corneous mass, being unable to grow upward as rapidly as before (due to the pressure from without), presses upon the periosteum covering the heads of the metatarsal bones and produces

FIG. 2

Histopathologic study of an excised callus from the plantar surface of the foot. It shows an increase of all the layers of the epidermis and a fibrosis of the derma. This fibrosis is probably due to a long standing inflammatory condition of the derma. To the left of the hypertrophied epidermis one sees the normal epidermis.

pain. The pain may be present only when walking or when the feet are resting upon the floor. However, the pain may be present at times when the feet are at rest, either in bed or upon a chair. Occasionally this pain may be substituted by a burning sensation. Just what causes this

burning sensation we are unprepared to say unless it is due to an inflammatory reaction in the derma.

A wart on the sole of the foot, verruca plantaris, or papilloma, as it is frequently called (Fig. 3) is probably due to a filterable virus. A papilloma is unquestionably of the same origin as the verruca vulgaris which frequently occurs upon the hands. Wile and Kingery[1] not long ago reported some interesting experiments in which they inoculated themselves subcutaneously with the filtrate of a desiccated wart and produced

FIG. 3a
Lateral view of foot presenting nineteen warts.

similar lesions upon themselves. From this experiment we must deduce that all warts, whether upon the hands or feet, are inoculable.

When such a virus implants itself in the skin we get, according to Wile and Kingery, "a hyperkeratosis, increase in the stratum granulosum, prolongation of interpapillary tufts, inflammatory reaction in the cutis and slight vacuolization in the cells of the rete." In other words, the rete pegs grow downward and the papillary bodies extend upward. At the summit of each papillary body are capillaries; when these capillaries are cut by shaving off a few epithelial cells we see pin-point bleeding which is

pathognomonic of warts. The blood coagulates within the injured capillaries and leaves brownish black pin-point sized spots. This we never see in a callus. The proliferation of these warts in the derma may be very deep. In the upper corium there is usually a slight inflammatory

FIG. 3b

Numerous warts on the plantar surface of the right foot.

FIG. 4

This patient had fifteen plantar warts over the head of the first metatarsal. These warts were surrounded by callus to such an extent that it was difficult to determine at first whether the mass was callus or a combination of callus and warts. There are a few isolated warts near by surrounded by callus which is easily seen.

reaction such as would occur round any foreign body. Removal of these lesions by the knife is attended by profuse bleeding and the dangers of auto-inoculation.

Clinically and histologically the differentiation between a plantar wart and a callus is no doubt clear to all. The terms callositas and

papilloma are occasionally used synonomously, but this is incorrect. The plantar wart is a papilloma, but a papilloma is never a callus. The word papilloma or plantar wart means an epithelial tumor in which the cells

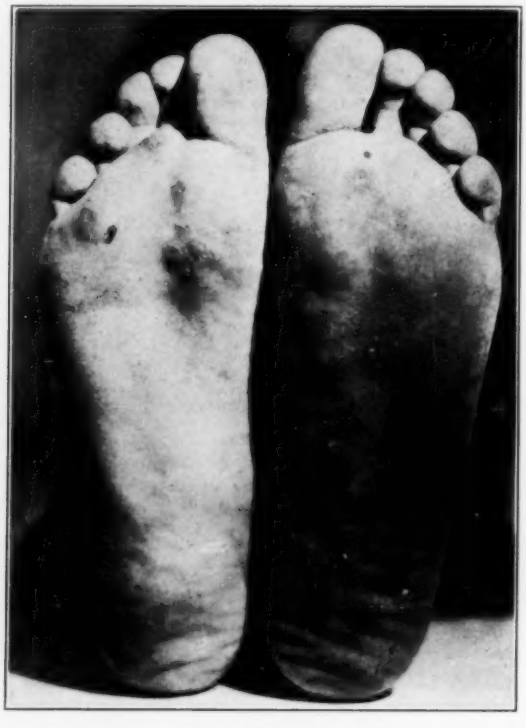

FIG. 5a

Represents a patient referred to us by Dr. Isadore Zadek. This patient had nineteen warts confined to the plantar surfaces of both feet and the lateral surface of the right foot. After one X-ray treatment the pain ceased abruptly in ten days and the warts were easily removed at that time by a comedone extractor. No recurrence.

cover finger-like processes or ridges of stroma. This irregularity macroscopically is not always as easily discernible in a plantar wart as the common wart upon the hand. The reason for this is due to the pressure exerted upon a plantar wart by the weight of the body. In a comparatively short time the surface becomes almost level with the contiguous

skin and frequently a group of these warts may lie beneath the surface of the skin. If there are two or three adjacent warts a small strip of callus may separate or surround them. In this instance the diagnosis may be somewhat confusing. Frequently there is seen a dime-sized area of callus containing a pea-sized wart within its center. In one patient who presented twelve closely grouped pin-head sized warts (Fig. 4) the amount

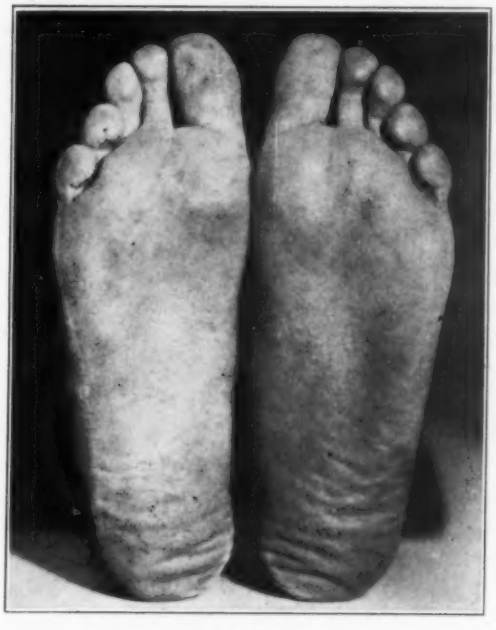

FIG. 5b

After one X-ray treatment (H 1¼ each treatment) plantar warts disappeared.

and arrangement of callus was so confusing that it was difficult at first to know whether one was dealing with pure callus or a combination of callus and warts. It frequently happens that isolated warts are surrounded by a millimeter or so of callus, as may be seen in Fig. 4. It is perhaps possible that the inflammatory reaction produced by a wart acting as a foreign body is responsible for this formation of callus. It occurs so frequently that it is more than a coincidence. However, usually there is no difficulty in differentiating a callus from a plantar wart.

Wickham and Degrais[2] in 1909 were the first to describe the treatment

of a plantar wart with radium. Since then Hazen and Eichenlaub[3] and MacKee[4] have all reported cases of plantar warts treated with roentgen rays. In a review of the literature we were unable to find any articles dealing exclusively with the X-ray or radium treatment of calluses. However, in a recent article by Howard Fox[5] upon "The Roentgen Ray in the Treatment of Skin Diseases" he cites three patients presenting calluses. These three patients were treated by him with X-rays and cured. No doubt many dermatologists have treated callosities with X-rays, but with the exception of Howard Fox they have unfortunately failed to publish their results.

X-RAY TREATMENT. These two lesions vary somewhat in their response to X-rays. It is easy to understand why when one considers their pathologic and etiologic differences. Before X-ray treatment of calluses is begun one should, if possible, seek advice from the orthopaedic surgeon, for many times the removal of pressure from the head of a metatarsal by a well fitting pad or brace may aid greatly in arriving at a permanent cure. There are also those patients in whom braces alone will not suffice to cure the callus; it is here that X-rays serve a useful purpose. However, if proper braces and X-rays are combined, a more rapid involution of the callus may frequently be obtained. X-rays will not alleviate pain from callus immediately, but occasionally after the second treatment the pain begins to diminish and this continues until a complete cessation of pain has been reached. The pain usually disappears a month or two before the complete disappearance of the callus.

TECHNIQUE. Strong caustics or keratolytics should be avoided two weeks prior to X-ray treatment. The callus should be trimmed as thinly as possible before irradiation. The callus should be carefully shielded with lead foil allowing no exposure whatsoever to the normal skin. The initial treatment should be one and one-half skin units, unfiltered. (Remer and Witherbee.[6]) The second and succeeding X-ray treatments should be given at intervals of one calendar month (30 days) unless some contraindication is noted. The second dosage may be exactly the same as the first. The patient frequently must return the third and even a fourth time before a complete cure is obtained. The dose of the third and fourth treatments may be the same as the first and second. One may, however, decrease the dose at the third treatment to one and one-quarter skin units unfiltered if the callus has undergone marked involution. On the other hand, if at the end of the second month or at the time of the third treatment the callus has not changed, the dosage may be increased to one and three-quarters or two skin units unfiltered. The above treatment has been

repeatedly used without the slightest mishap. One may resort to filtered radiation when necessary (one and one-quarter to two skin units filtered through one mm. of aluminum. [MacKee.[7]]) The question of filtered or unfiltered radiation will depend upon the thickness of the lesion and the experience of the physician. If the callus has not responded by the end of the fourth month X-ray treatment should be suspended. There is no doubt that after a certain number of X-ray treatments the irradiated tissues acquire a certain immunity. This is shown not only by recalcitrant callosities, but also by repeatedly X-rayed psoriasis, etc. There is one case of resistant callus which we have had the misfortune to treat. Every conceivable form of treatment has been tried such as excision with recurrence, radium, X-rays, both filtered and unfiltered, without the slightest result. This, of course, is the exception.

CHART

Average

	No. of patients	Age	Sex	Dur.	Number	No. of treatments	Dosage per treatment unfiltered	Per cent. of cures
Callus.....	27	45	F. 60% M. 40%	2 yrs.	61	4	1½ skin units	85
Verrucae....	12	20	F. 65% M. 35%	3 mos.	59	3	1¼ skin units	91

The percentage of cures of calluses might have been increased had all these patients obtained proper braces and come regularly for X-ray treatment. The longer the callus has been present the more resistant it is to X-ray treatment. We believe that when we have failed it was because the inhibitory dosage had probably not reached the basal layer. This may be easily understood if we recall that when one skin unit is given only this amount reaches the surface of the skin. Between the basal layer and the stratum corneum are numerous keratinized cells which act as a filter, preventing the full dose from reaching the basal layer. It is necessary for at least one skin unit unfiltered to reach the basal layer in order to produce an inhibitory effect upon these cells, thereby preventing reproduction for at least one month. If at the end of this month a second inhibitory dose is given the basal cells do not reproduce for another month and the callus is gradually thinned until it eventually disappears. Filtered radiation in general for calluses might be superior to unfiltered; however, our results with unfiltered radiation have been quite satisfactory. At a later date we will report upon a series of cases treated by filtered radiation.

At the present time it is believed that the results are practically uniform, but this is only drawn from a few filtered cases—too few to make comparison.

The treatment of verrucae upon the plantar surface of the feet is a somewhat different procedure. Whether we have one or several lesions the following technique is the same. The contiguous skin should be carefully shielded by lead foil. The initial dose should be one and one-quarter skin units unfiltered. The second treatment should be one month later, giving the same dosage as before. Usually between the first and second treatment or second and third the pain will abruptly disappear. On the other hand, the pain may gradually disappear, requiring from ten days to two weeks after the first or second treatment. Frequently after one or two X-ray treatments one may pick the small wart out of its shell by the sharp end of a comedone extractor without pain or inconvenience to the patient. The wart after X-rays seems to loosen itself from the adjacent parts, easily permitting its removal. This bears some relation to the epilation phenomena. There is usually left a deep hole which is soon filled by normal tissue. We always attempt the removal in this manner, and if successful the treatment is thereby shortened.

If, on the other hand, callus has surrounded the wart it is practically impossible to remove it *en masse;* further irradiation will be necessary to cause complete involution, not alone of the wart but also of the surrounding callus. Here it may be necessary to employ one and one-quarter to one and a half units unfiltered in these cases. As a rule, the simple plantar wart without callus is a comparatively easy condition to eradicate, frequently requiring but one or two treatments; whereas if complicated with callus, three or four treatments are the rule, and occasionally failure results. These lesions are frequently excruciatingly painful and recourse to proper padding may be necessary. One may remove these papillomata with caustics, fulguration, or curettement, but these procedures are usually so painful that the patients refuse further treatment.

Radium will give the same results as X-rays in both callus and wart. The time per treatment with X-rays is, however, much shorter than with radium, and furthermore X-ray dosage may be measured more accurately.

CONCLUSIONS

1. The X-ray is the method of choice for callus and plantar wart.
2. Orthopaedic surgeon and dermatologist should co-operate when possible in the treatment of these two conditions.
3. There are distinct clinical, etiologic, pathologic, and therapeutic differences between callositas and papillomata.

We desire to express our thanks especially to Dr. B. P. Farrell of the New York Orthopaedic Hospital, who has been kind enough to refer many of the calluses and plantar warts to us which we have treated, both privately and in the clinics.

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ACTIVITIES OF BONE CELLS*

BY SYDNEY M. CONE, M.D., F.A.C.S., BALTIMORE

From the Pathological Laboratory of the University of Maryland

This work is the result of the study of bone from more than two hundred and fifty autopsies, surgical pathology, fetuses, animals, and bone grown experimentally in muscle. In these the basic principle underlying the activity of the bone cell is modification in circulation and chemistry. I have drawn an analogy between bone when passively, actively, or alternately congested, and edematous soft parts and organs under similar conditions.

In other publications I have called attention to the relation between bone pathology and general pathology. This paper deals with the bone cell and its actions as a variety of connective tissue cell.

The activity of the bone cell is referred to by Virchow, von Recklinghausen, Ziegler, Paget, Macewen, Fehr, Bonome, Bast, Arnold, Lossen, Goldthwait, Painter, Osgood, Gallie, Haas, Loven, Phemister, Billroth, Knaggs, and many others, yet it is often overlooked.

The close relationship of bone cells and marrow cells is indicated in writings of Jordan, Arnold, Ziegler, and Maximow. The transmutation of marrow cells into others of their class is written of by those who consider leukemia a variety of sarcoma or who see different varieties of marrow cells in leukemias. (Ewing, Osler, Banti, Warthen, Pagniez, Blatteis, Ziegler, and Scott.)

The change of bone to fibrous tissue is recorded in numerous cases of osteitis fibrosa (Freiberg, Langenskiold, Painter, Knaggs, etc.).

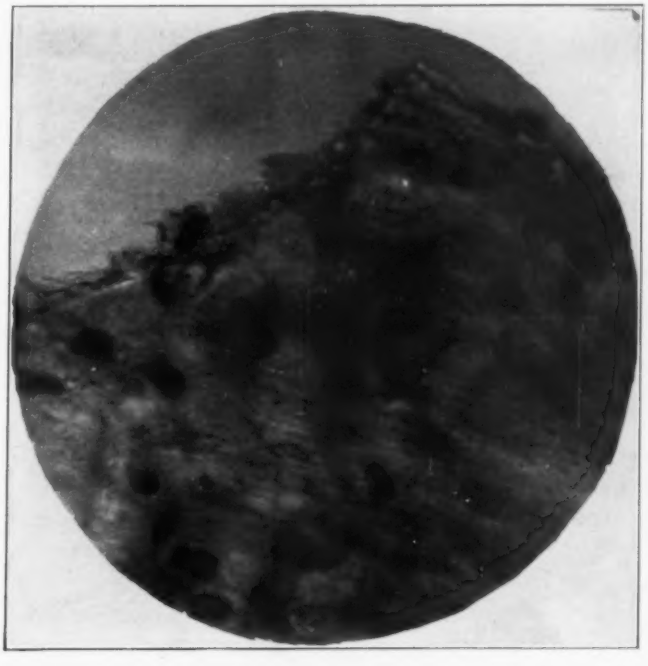
Metaplasia of connective tissue cells to bone cells occurs in various organs and tissues, and has been experimentally produced (Asami, Dock, Pearce, Harvey, Moschowitz, Wells, Bunting, and Ziegler).

Pathology teaches us that the bone cell may become an embryonal connective tissue cell (sarcoma), osteoclast, fibroblast, cartilage cell (Ziegler, Kölliker, Wegner, Cornil, Ranvier, Shakespeare, etc.). Myeloma illustrates the activity of marrow cells as an embryonal connective tissue cell

*The references are to be found in the bibliography of a recent publication in Journal of Bone and Joint Surgery.

tumor. Different authors describe various kinds of marrow cells in this sarcoma (Glynn, Wright, Osgood, Lewis, etc.).

If marrow is a connective tissue substance and the bone cell is of the same class, derived from the same parent cells, there seems no reason that the two could not interchange activities. I give evidence that the bone cells revert to cells of marrow, as the marrow cells take the part of bone cells



1069. Undecalcified. Old myocarditis bone. Vital absorption. Bone cells proliferated and free.

in endosteal bone formation. This interrelationship is quite evident in the embryology of bone, where the blood vessels displace cartilage, leaving bone and marrow cells in their wake. This is seen in the marrow-containing bone in sclerotic ovaries (Moschowitz) and sclerotic aorta (Bunting). I have seen it in thyroid, kidneys, and other organs.

The conditions which illustrate manifestations of bone activity are presented under the following headings:

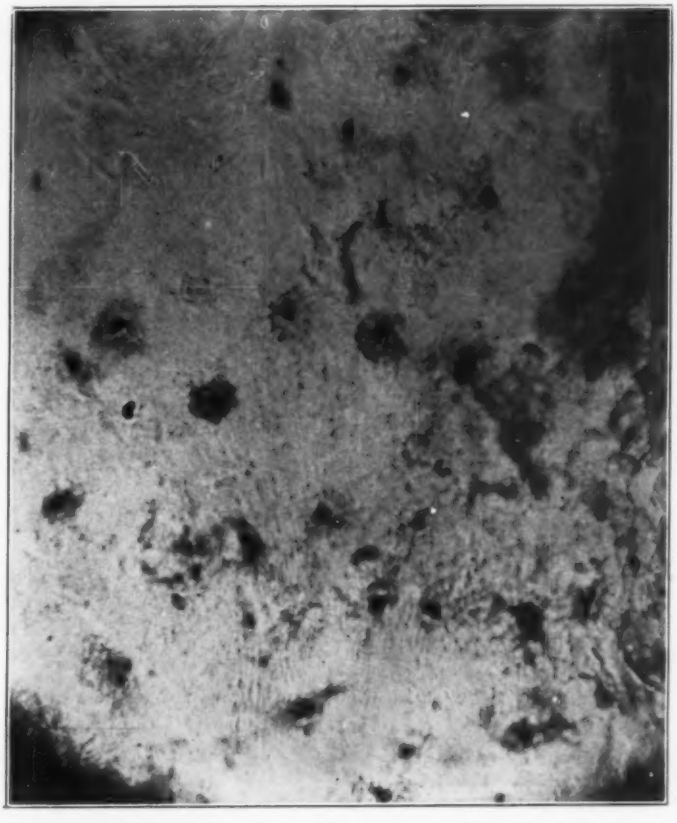
A. Cardio-vascular disease with chronic passive congestion.
B. Localized vascular disease with thrombosis.
C. Pernicious anemia, secondary anemia, leukemia, Hodgkin's disease, carbon monoxide and wood alcohol poisoning.
D. Inflammatory bone disease.
E. Fractures and transplantation of bone fragments.
F. Tumors of bone.
G. In vitro growth.

A. In all cases (Photographs 1069–891) of long continued cardio-vascular disease with chronic passive congestion, the ribs are deeply congested, edematous, and pigmented. The lacunae, canaliculi, cells, and matrix contain blood pigment. Red blood cells are often seen in enlarged lacunae and clefts, due to edema. The lamellae are swollen and, in older cases, their lines become obliterated with the solution of salts (vital absorption of von Recklinghausen and Axhausen). At the borders of Haversian canals one sees a line usually referred to as "due to osteomalacia." In undecalcified sections the calcium salts are irregularly scattered or absent. The lacunar areas hold the salts most tenaciously and the Virchow territories are marked thereby. In the center of this territory the bone cell is enlarged and its nucleus well stained. The outermost edge of this area is well defined by a hematoxylin or fuchsin stained granular line. The inner zone is less defined and frequently looks like a mass of granular protoplasm of the bone cell. All the cells of the spongiosa and bordering Haversian canals stain well in their round enlarged lacunae.

There is a coalescence of lacunae with coincident enlargement and division of the bone cell. The nucleus is most commonly incompletely divided and lobulated. There are two or three large cells in enlarged lacunae. This is always most marked near the borders of the trabeculae traversing the marrow cavity and along the borders of the Haversian canals. This border is granular, meshed like a network of spongy matrix or homogeneous. In it are large bone cells still enmeshed or being liberated into the marrow. Here they grade off as a syncytium, polygonal cells, stellate cells, or huge triangular protoplasmic cells very sharply outlined.

The protoplasm often takes the basic stain, is granular, and the cell mass resembles callus in its early formation. The nucleus of the cells is rich in chromatin, eccentrically located as a rule and contains one or two large nucleoli. Kölliker's osteoclasts are sometimes seen near the syncytium or cuboidal cell masses. The marrow is full of "large cells" resembling myelocytes. There are many normoblasts, megalokaryocytes and frequent fibrosis—"reversion to the embryonal." In some cases osteoblasts line the

cancelli near areas of lacunar and vital absorption. This is marked in the chronic passive congestion of Paget's Disease (Cone: Journ. Bone and Joint Surg., Oct., 1922). Ten of my cases resemble osteitis deformans of Paget in the erratic architecture, the bone cell activity, the "large cell"



891. Chronic passive congestion. Paget's osteitis deformans. Age 85. Reversion of bone matrix. Bone cells active. Undecalcified.

overgrowth of marrow, reversion to the embryonal state, the fibrosis, vital and lacunar absorption of bone. In some, the trabeculae have become fibrous. In others the bone substance is a finely granular matrix containing numerous oval and round nuclei with two nucleoli. These nuclei show division clefts and some are completely divided. The "large cell" accumula-

tion in the marrow, like the marginal cells, is often so great as to resemble large round cell sarcoma or mylogenous leukemia. Again the appearance is that of granulation tissue minus the polymorphonuclear leucocytes.

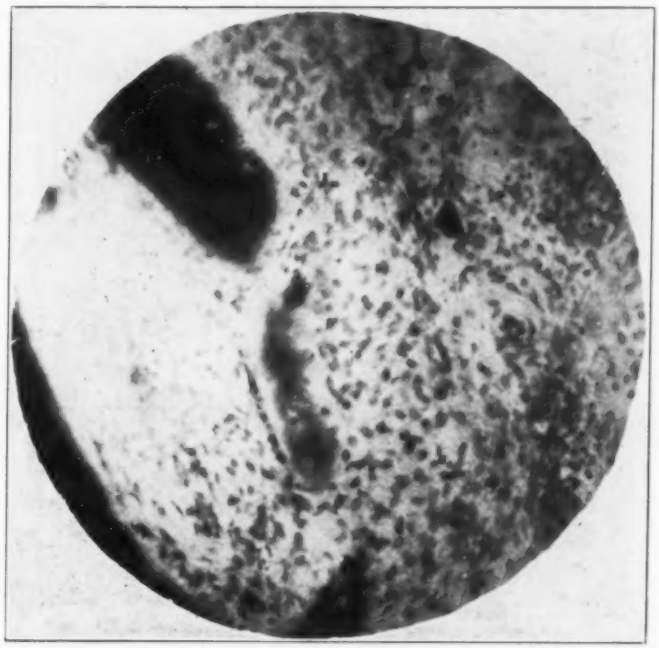
The entire picture is that of metaplasia—a reversion to the embryonal state.

SP12003. Arteriosclerosis—Diabetes. Toe. New bone. Reversion with lacunae and vital absorption. Marrow fibrous.

(Photographs 12003–2792.)

B. In bones of members amputated on account of arteriosclerosis and thrombosis, we see new formed bone trabeculae lined by osteoblasts and young cellular fibrous marrow. When the process has existed for a long time and edema is excessive, the cancelli of old and new bone all show the lacunar and bone cell changes narrated under A. The newer cancelli in reversion demonstrate the cell and lacunar changes most remarkably. The

matrix throughout is a spongy meshwork containing coalescent lacunae and enlarged dividing bone cells. The "large cells" are present in the marrow and along the borders of cancelli mixed with spindle cells and mast cells. Fibrosis of the marrow is a constant finding. The skin and subcutaneous tissue and muscle are the seat of round cell infiltration and fibrosis, reminding us of the experimental work of Barney Brooks in cutting off the venous circulation in muscle.



HH2792. Arteriosclerotic limb. Toe. New bone and fibrous tissue. Resolution of cancelli; cells freed from the new bone.

The keratosis sometimes associated with passive congestion of Paget's osteitis deformans, the dense connective tissue formation in elephantiasis with edema, and the clubbed fingers of long standing heart disease, must be considered herewith.

(Photographs 978, 1005, 951, 973.)

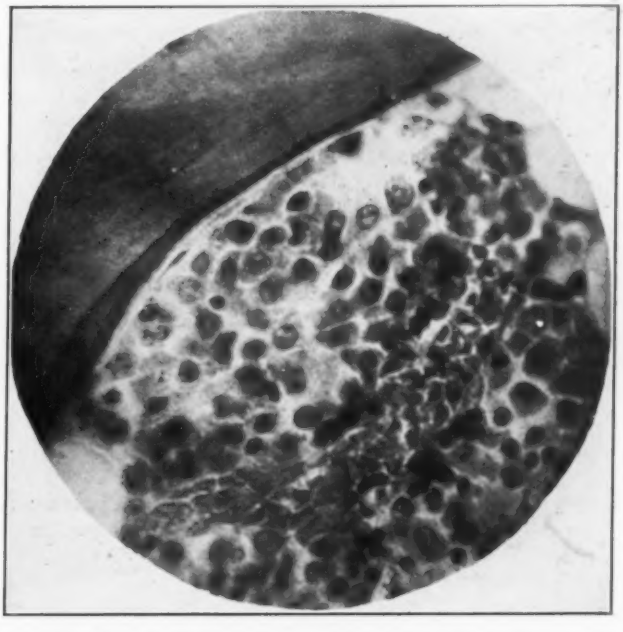
C. In the cases of secondary and pernicious anemia, carbon monoxide poisoning, leukemia, Hodgkin's disease, phosphorous poisoning, wood alcohol poisoning, and general infections, edema is pronounced in the bone.

1005. Leukemia. Enlarged lacunae. Bone cells active. Cleavage of matrix.

978. Marrow of pernicious anemia. Fibroblasts and normoblasts.

The retrogressive change (vital absorption) in matrix with enlarged and confluent lacunae and swollen lamellae is more prominent than the bone cell activity. The marrow reversion to the embryonal is active. In the leukemia cases the "large cell" multiplication is very great at the borders of the vitally absorbed bone cancelli, where the bone cells are enlarged and nuclei dividing.

In Hodgkin's disease, pernicious anemia, and carbon monoxide poison-



951 CO Poisoning. Large polygonal cells lining cancellus and filling marrow.

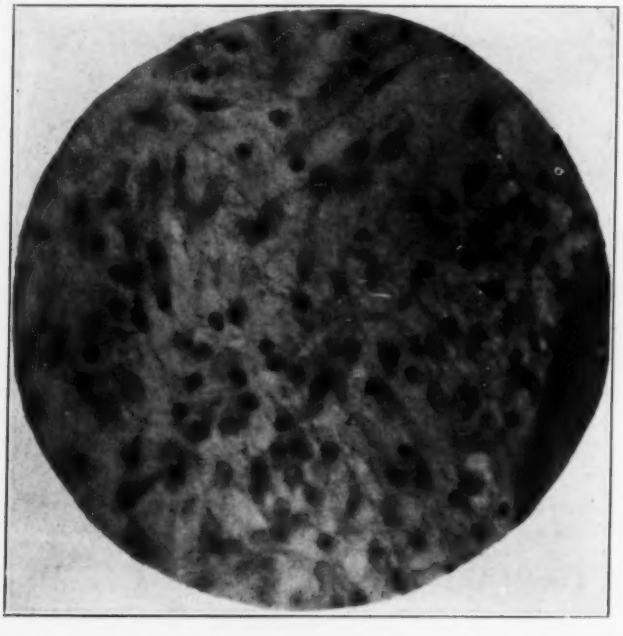
ing, besides the enlargement of lacunae and activity of the bone cells and the large cell hyperplasia in marrow, there is connective tissue formation. In pernicious anemia the large cell increase is very great and resembles sarcoma (this has been noted by Muir, Grawitz, and Bunting).

(Photo 1643.)

D. Near areas of tuberculous infiltration and caseation of bone, the bone trabeculae commonly demonstrate the changes seen in passive congestion. The "large cells" (multiplied bone cells) released in the regressive change form a syncytium or cuboidal cell masses on the borders of tra-

beculae. This looks like and is commonly known as callus. Not infrequently good new bone is seen in these areas. I have two cases where stalactitic bone trabeculae are seen in hemorrhage under the periosteum near areas of tubercular infiltration. I reported one of these cases in the Journal of Orthopaedic Surgery in May, 1911.

In acute and chronic osteomyelitis we see the preliminary vital absorption of circulatory disturbance. This becomes extreme with pus

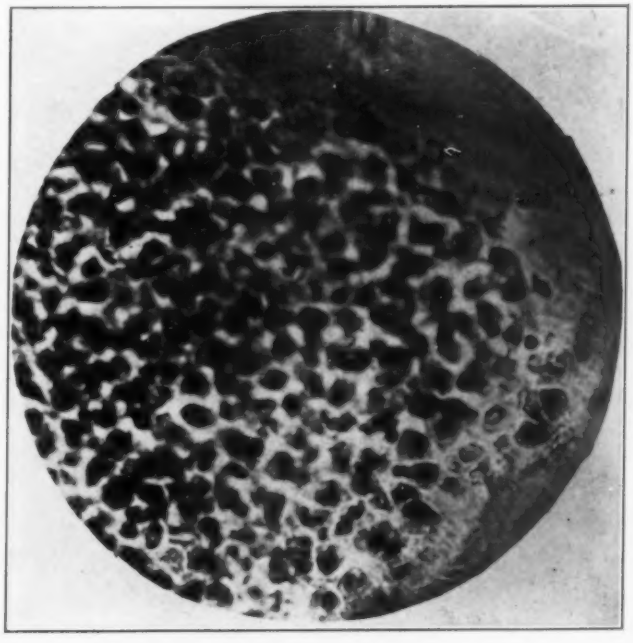


973. Hodgkin's disease. Bone cancellus spongy. Marrow fibrous.

formation. Lacunar erosion accompanies the formation of granulation tissue. Necrosis supervenes, yet on the outskirts of these more severe changes we always see evidence of stimulation and active proliferation of the bone cell, as in the edematous areas of passive congestion. I have seen new bone formation in the presence of pus. The old sclerotic bone in chronic osteomyelitis is due to the renewed osteogenetic activity of enlivened bone cells following the preliminary softening of matrix and proliferation of bone cells during the congested edematous period.

E. The changes seen in trauma and inflammation of soft parts have

their counterpart in bone. The granulation tissue of bone merely adds the young bone cell to the unknown cells of this embryonal tissue. The changes in bone following fracture involve the vital and lacunar absorption, necrosis, and the formation of callus. The callus forms in the areas of best circulation and nutrition and of least destruction. Where necrosis of spicules is present, we do not see the processes described above. It is



1643. Bone adjacent to cancer. Matrix softened. Lacunae enlarged. Bone cells dividing and free in marrow.

commonly to the ends of the fixed bone with its good circulation that we look for bone cell activity. Not infrequently a fragment loose in blood fibrin and cellular exudate gives the picture seen in edematous congested bone of cardio-vascular disease (see A). The lamellation is lost, the bone becoming homogeneous, the cells multiplying as large polygonal callus cells. They are often seen in the process of dividing within lacunae before the homogeneous stage has been reached. A piece of spongiosa transplanted from the ilium into muscle (photo 1896) illustrates the callus formation about bone undergoing vital absorption. The deeper parts of the cancelli

contain widened confluent lacunae, enlarged deeply stained bone cells and finely granular matrix. The edge of the spicule fades gradually into a homogeneous film, which contains oval and round nuclei. This film next appears divided into polygonal areas (large cells) with peripherally placed nuclei—the bone cells. These may now be called osteoblasts, for they assist in the deposit of calcium salts and become encased as bone cells in the hardening bone structure.

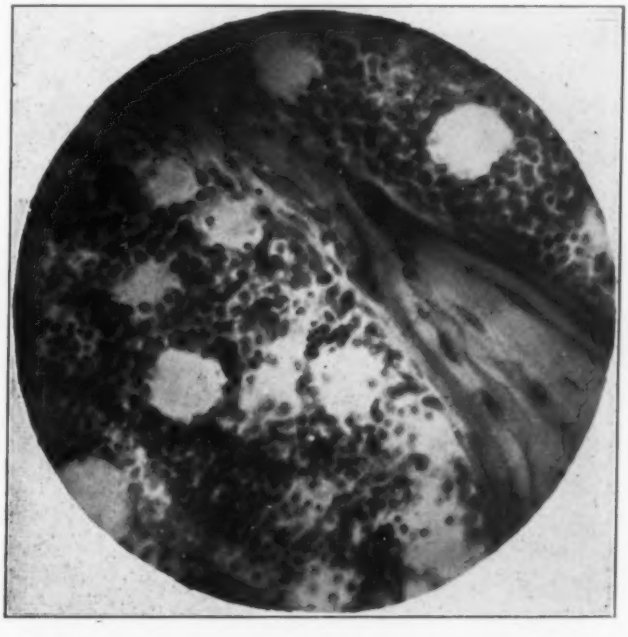
SP13153. Sarcoma of Bone. Reversion of Bone Cancelli. Lacunae enlarged and coalescent. Bone cells multiplying and free in marrow.

F. Photo 13153. In sarcoma of bone we see metaplasia of a connective tissue substance in its most manifold extensions. The hemorrhage, edema and vascularity are greatly responsible. We not only see the resolution of bone matrix liberating the dividing and multiplying bone cells, but also a progressive condition—new bone formation and cell multiplication in the form of embryonal connective tissue cells. The old bone trabeculae are swollen, lamellae widened, lacunae enlarged and confluent. The bone cells divide actively, filling lacunae and the sinuses formed by

confluent lacunae. Cartilage cells sometimes result from the bone cell metaplasia. The cells are liberated, multiplying actively in the marrow as sarcoma cells. The matrix becomes homogeneous and cellular and new bone formation results.

(Photo 1643.)

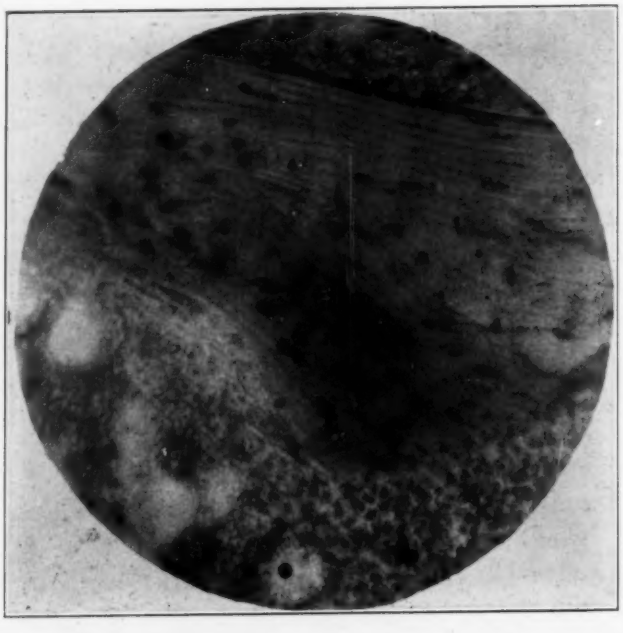
Cancer in bone is accompanied by passive congestion with all its accompaniments described above. There is vital and lacunar absorption



1015a. Age 60. Chronic passive congestion. Reversion of bone. Cells freed.

and mesoblastic cell activity. Osteoclasts, large cells, fibroblasts, and connective tissue formation fill the marrow cavity about the cancer cells. The "large cells" from bone cells are seen in a syncytium and cuboidal cell masses on the borders of resolving bone trabeculae. Numerous megalokaryocytes, normoblasts, and giant-cells mixed with the large round or polygonal cells fill the marrow. The reversion to the embryonal condition is most noteworthy in cases of metastases from gastro-intestinal cancer.

I have described cartilage formation on the outskirts of the metastases



1015c. Chronic passive congestion. Age 60. Softened bone. Bone cells proliferating.

1015b. Age 60. Reversion of bone matrix. Bone cells multiplying.

where great vascular congestion was present. (*Johns Hopkins Hosp. Bull., 1898.*)

New bone formation is evident. Osteoblasts line trabeculae in the neighborhood of the "large cell" accumulations.

G. (Photo XC.) Bone spicules from the spongiosa of rabbits. These spicules, in normal salt solution mixed with blood plasma, were kept seven days in the thermostat. They show some of the changes seen in chronic passive congestion.

1017. Age 63. Bone resembling Paget's osteitis deformans. Osteoblasts lining Haversian canals. Cellular marrow.

The granular bone becomes homogeneous along the borders of the cancelli. The bone lacunae are enlarged and confluent.

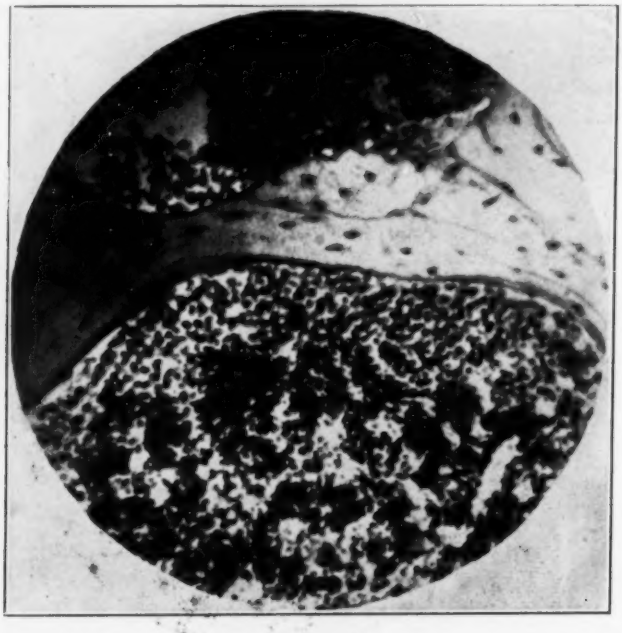
The bone cells are swollen and the nuclei dividing.

The bone up to the fourth day merely shows swelling of lamellae and cells. The staining is not as clear as in the six and seven day specimens.

SUMMARY

The conditions described indicate that bone under pathologic conditions may act like any other tissue. There is a reversion of its various

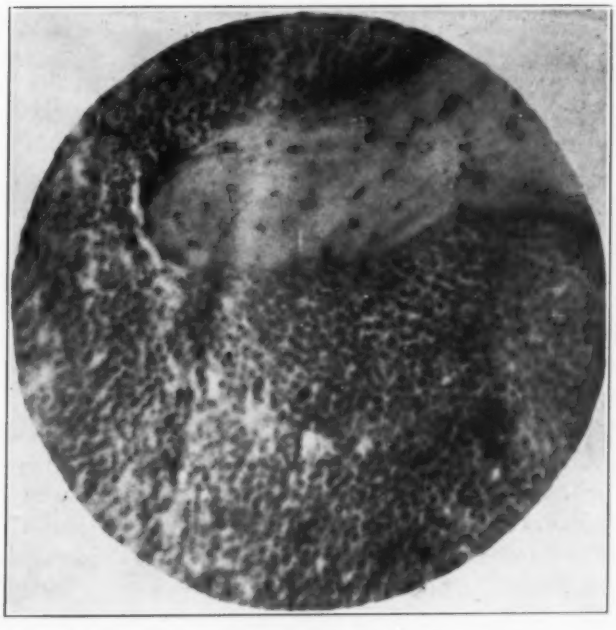
constituents to an embryonal condition and a remodelling of the bone in ways suitable to the change in its circulation and chemistry. There is a coincident reversion of bone cell and marrow cell to the embryonal state. New bone and new connective tissue result therefrom. The most important factor in bone-cell renewed activity is passive hyperemia and edema.



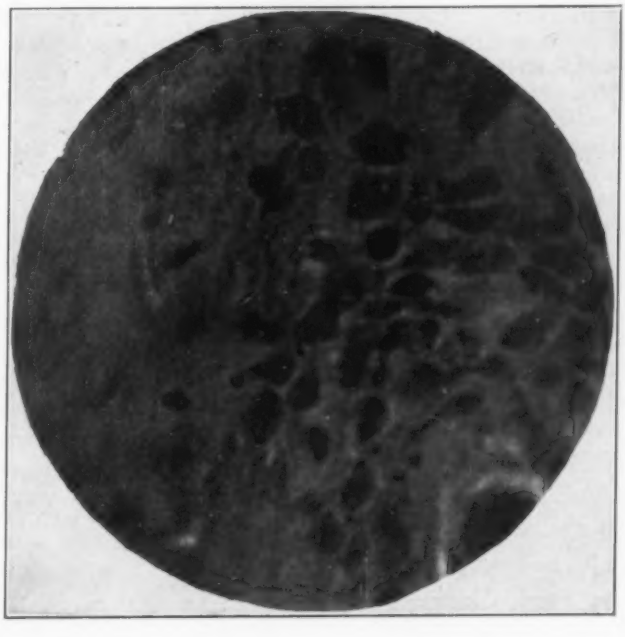
1067. Bone of Typhoid. Granulation tissue. No polymorphonuclears. Edematous matrix.

Edema dissolves the salts, softens the bone matrix, and is instrumental in the enlargement and confluence of lacunae. The bone cell is released before it again becomes active. The bone cells, notably those at the margins of cancelli, enlarge, divide, and are now free in the marrow. They form a part of the marrow as possible bone formers. They are seen as a syncytium or as cell masses resembling callus, and grade off into new bone.

All of these observations on the activity of the bone cell were from bone of individuals beyond the age of active bone growth.



10056. Leukemic bone marrow cancellus disappearing.



1563. Bone resolution adjacent to a tubercular focus. Bone cells forming callus.

TECHNIQUE

The bone was placed in 10% formalin at once. In a week a section 1 cm. wide was sawed off transversely and placed in 10% hydrochloric acid for two days. Seldom is a longer time required for complete decalcification. It was then washed in running water for two hours, then placed in 10% formalin for a day or more. Next it went through the alcohols mounted in celloidin and cut. All specimens were stained with hematoxylin and eosin. The result was quite as good as in the staining of soft tissues. To better depict red blood cells and bone cells, carbol fuchsin followed by formalin was used. Scarlet red and osmic acid were used to stain fat. In the examination of free hand undecalcified sections, I used Bast's gentian violet method as well as alum carmine and carbol fuchsin mounting in glycerine or Canada balsam.

Polychrome methylene blue was used to help differentiate cells of the marrow and stain the bone cell without affecting the matrix.

Fresh bone was examined from trabeculae or thin slivers were cut with a surgeon's knife and stained as above. After placing in Canada balsam, it may be further divided on the slide if necessary. Glycerine mounts were frequently used.

DISCUSSION

DR. ALBERT H. FREIBERG, Cincinnati: This paper is certainly very suggestive with regard to the metaplastic activity of cells according to the environment in which they find themselves. While this is true, at the same time it seems to me that we have here a work which covers a tremendous amount of pathology in the human body and which represents an effort to prove the nature of cells almost entirely by means of their morphologic characteristics. This may be the only means we have in our hands at the present time, but we should be at the same disadvantage in our reasoning as if we were to attempt to determine the characters of a group of men by means of their garments and without being able to follow them in their behavior. It has been a long time since I have had an active participation in this kind of work and I am very sorry that I can add practically nothing to the discussion of the subject.

DR. SYDNEY M. CONE, Baltimore (closing the discussion): At one time Dr. Freiberg wrote about the metaplastic activities of fibrous tissue. We now know more about bone cells' metaplasia. That was taught us in our student days and we do not forget what we once knew about bone cells.

DIAGNOSIS AND PROGNOSIS OF BONE SARCOMA*

BY ANATOLE KOLODNY, PH.D., M.D.

From the Department of Surgery, University of Iowa Medical School

It is no exaggeration to say that the vivid interest in sarcomas of bone in America was aroused by the work of the Sarcoma Registry and its leaders. The descriptive stage of these tumors is not yet at its end. The unsurpassed reviews of bone tumors of Ewing, Bloodgood, and others form the basis upon which our further studies are to be built. Additional knowledge of the natural history of these tumors is still to be acquired. Meanwhile we have reached a stage when statistical reports are overwhelming the literature of this subject. Statistics are usually only of relative importance in surgical conditions, where the individuality of the surgeon and the stage of the development of the condition play an important rôle; even of more doubtful value are statistics of bone tumors, when based upon results of treatment only, since the stage of the development of the disease is of the uppermost importance. An analysis of individual cases which are representative, clinically and morphologically, is far more significant than such statistics.

It was thought that some disputable points in the diagnosis and prognosis of sarcomas of bone might well be illustrated by such an analysis.

The points emphasized below are the result of a clinical, roentgenologic, and pathologic study of twenty-five cases of bone sarcoma observed in the Iowa State University Hospital during the ten years between 1915 and 1925. Only cases of involvement of the long pipe bones, and only those of which histologic preparations and roentgenograms were found on file and which it was possible to follow up to the end of April, 1925, are taken into consideration.

The long pipe bones are selected for several reasons. The roentgenologic findings in a tumor of a long tubular bone are easier to interpret. The surgical problems involved are quite different in sarcomas of the long bones from those of other bones of the skeleton. Finally it is difficult to assume that the medullary canal of a long bone and its characteristic blood supply do not play a certain rôle in the course of the disease.

*Presented before the meeting of the American Orthopaedic Association in Washington, D.C., May 6, 1925.

TABLE 1. OSTEOGENIC SARCOMA AND GIANT-CELL TUMOR

Case.	Age.	Sex.	Onset of symptoms.	Site.	Treatment before and after admission to the University Hospital.	Clinical diagnosis.	Roentgen-Ray diagnosis.	Pathologic diagnosis, after examination of sections on file and of new cut sections.	Result.	Life duration after onset of symptoms.
I.	15.	F.	Trauma to left hip in spring, 1922. Pain since July, 1922.	Shaft of the left femur.	Was treated for "rheumatism." Aspiration of the tumor June 29, 1923. Roentgen treatment.	No diagnosis made.	Osteogenic sarcoma.	Cellular spindle cell periosteal sarcoma.	Died May 4, 1924.	Two years.
II.	26.	M.	Repeated traumatizing of the internal malleolus of the right leg in winter, 1920. Pain since April, 1920.	Lower end of the right tibia.	Was treated for "an inflammation of the right ankle." Amputation of the thigh on June 19, 1920.	Osteogenic sarcoma.	Osteogenic sarcoma.	Cellular spindle cell periosteal sarcoma.	Died in May, 1922.	Two years.
III.	5.	M.	Trauma to the right knee in April, 1924. Pain since August, 1924.	Lower end of the right femur.	Biopsy in August, 1924. Coley's toxins in August and September, 1924. Roentgen treatment in October, 1924.	Osteogenic sarcoma.	Osteogenic sarcoma.	Cellular spindle cell periosteal sarcoma.	Died April 4, 1925.	One year.
IV	25.	M.	A swelling was noticed in the summer of 1918. Pain since May, 1922.	Great trochanter of the left femur.	Excision of the tumor on October 9, 1922.	No diagnosis made.	"Tumor attached to the periosteum."	Sclerosing periosteal sarcoma.	Died October 20, 1922.	Four years.
V	29.	M.	Repeated trauma. Pain in the right hip since August, 1919.	Upper end of the right femur.	Was treated for "rheumatism." Drainage for tuberculosis of the right hip in October, 1919. Curettage on November 29, 1919.	Tuberculosis.	No diagnosis made.	Cellular spindle cell periosteal sarcoma.	Died January 4, 1920.	Four and a half months.
VI.	22.	F.	A trauma to the left knee in December, 1920. Pain since January, 1921.	Head of left tibia.	Curettage for osteomyelitis in May, 1921. Curettage for osteomyelitis in July, 1921. Amputation of the thigh on August 13, 1921.			Solid subperiosteal sarcoma.	Died January 1, 1922.	Two years.
VII.	10.	M.	Night pain appeared in November, 1923.	Upper end of the left humerus.	Exploratory incision on January 5, 1924. Roentgen treatment.	Osteomyelitis	Osteomyelitis.	Cellular subperiosteal osteogenic sarcoma.	Died in December, 1924.	One year and one month.
VIII.	6.	F.	Trauma to left knee in September, 1915. Pain since the middle of October, 1915.	Lower end of the left femur.	Treatment for "sprain." Amputation of the thigh on December 5, 1915.	Osteogenic sarcoma.	Osteogenic sarcoma.	Solid cellular subperiosteal and central osteogenic sarcoma.	Died in October, 1916.	One year and one month.
IX.	12.	F.	Trauma to the left knee in November, 1915. Pain appeared ten days after the trauma.	Shaft of the right femur.	Treatment for "rheumatism." Immobilization. Exploratory incision and drainage on February 3, 1916.	Probably sarcoma.	Probably sarcoma.	Solid cellular subperiosteal sarcoma.	Died July 15, 1916.	Eight months.
X.	60.	M.	In November, 1918, the patient first noticed tenderness of right knee. A swelling of the knee appeared in February, 1919.	Head of right tibia.	Treated for "rheumatism." Amputation of thigh on November 24, 1919.	No diagnosis made.	Arthritis.	Solid subperiosteal sarcoma.	Died in May, 1921.	Two years and six months.
XI.	8.	F.	The country nurse discovered a swelling in January, 1923.	Proximal end of the left ulna.	Exploratory incision on March 20, 1923. Roentgen treatment after the exploratory.	Probably sarcoma.	Probably sarcoma.	Cellular central sarcoma.	Died in October, 1923.	Ten months.
XII.	33.	F.	Trauma to the right hip in spring, 1915. Pain appeared in summer, 1915.	The neck of the right femur.	Immobilization. On July 31, 1916, an exploratory incision. Roentgen treatment.	No diagnosis made.	No diagnosis made.	Cellular central sarcoma.	Died in October, 1916.	One year and two months.
XIII.	17.	M.	Trauma to the left leg in the end of March, 1922. Pain since April 20,	Upper end of the left fibula.	Amputation of the thigh on May 4, 1922.	Osteogenic sarcoma.	Osteogenic sarcoma.	Solid central osteogenic sarcoma.	Died in May, 1923.	One year and one month.

			1915. Pain appeared in summer, 1915.	right femur.	Immobilization. On July 31, 1916, an exploratory incision. Roentgen treatment.	No diagnosis made.	No diagnosis made.	Cellular central sarcoma.	Died in October, 1916.	One year and two months.
XIII.	17.	M.	Trauma to the left leg in the end of March, 1922. Pain since April 20, 1922.	Upper end of the left fibula.	Amputation of the thigh on May 4, 1922.	Osteogenic sarcoma.	Osteogenic sarcoma.	Solid central osteogenic sarcoma.	Died in May, 1923.	One year and one month.
XIV.	14.	F.	Trauma to the right knee in May, 1924. Pain appeared in the middle of June, 1924.	The head of the right tibia.	Treated for "rheumatism." Amputation of the thigh on December 22, 1924.	Probably sarcoma.	Probably sarcoma.	Central solid sarcoma? Border line type of a giant-cell tumor?	No metastases in May, 1925.	
XV.	12.	F.	Pain in the left thigh appeared in June, 1924.	Shaft of the left femur.	Treated for "rheumatism." Roentgen treatment in August and October, 1924. Disarticulation of the left thigh December 5, 1924.	Osteogenic sarcoma.	Probably sarcoma.	Sclerosing central osteogenic sarcoma, with vascular and cellular areas.	No metastases in May, 1925.	
XVI.	54.	M.	Trauma to the left shoulder in December, 1914. Pain appeared in September, 1915.	Upper end of the left humerus.	Treated for "rheumatism" until October, 1915. "Electric" treatments in November, 1915. "Mercury treatments" in December, 1915. "Reduction of dislocation" in September, 1917. In January and February, 1918, tapping of the shoulder joint. In February, 1918, a lymph node was removed from the left axilla. An exploratory incision in May, 1918. Roentgen treatment.	No diagnosis made.	No diagnosis made.	Sclerosing central osteogenic sarcoma.	Died September 1, 1918.	Three years and ten months.
XVII.	35.	M.	Trauma to the left ankle in 1913. A swelling was noticed one month later.	Lower end of left tibia.	Local excision in 1915. Local excision of a recurrence in November, 1918. Amputation of the left leg in February, 1919. Roentgen treatment.	Osteoma.	Osteoma.	Sclerosing central osteogenic sarcoma.	Died October 27, 1921.	Eight years.
XVIII.	24.	M.	Tenderness of the right elbow appeared in May, 1918.	Proximal end of the right ulna.	Amputation of the right arm on January 9, 1919.	Osteogenic sarcoma.	Osteogenic sarcoma.	Myeloma with hemoglobin holding cells.	Died in January, 1920.	One year and seven months.
XIX.	12.	M.	Pain since March, 1922.	The upper end of the right fibula.	Treated for "rheumatism." Amputation in May, 1923.	No diagnosis made.	No diagnosis made.	Telengiectatic sarcoma.	Died in March, 1924.	Two years.
XX.	Eight weeks.	F.	Congenital.	Right tibia.	Amputation on October 10, 1917.	Sarcoma.	No diagnosis made.	Encapsulated extraperiosteal fibrosarcoma.	No metastases in May, 1925.	
XXI.	15.	M.	A swelling appeared in January, 1923.	Upper end of the left tibia.	Osteopathic treatments. Curettage and drainage July 7, 1923. Treatment for infection of the wound.	No diagnosis made.	No diagnosis made.	Giant-cell tumor.	Well in May, 1925.	
XXII.	52.	M.	Soreness of the left knee appeared in December, 1919. A swelling noticed soon afterwards. Fracture.	Lower end of the left femur.	Treatment of fractures by immobilization. Curettage and drainage on October 10, 1921. Treatment for infection of the wound.	Giant-cell tumor.	Giant-cell tumor.	Giant-cell tumor.	Well in May, 1925.	
XXIII.	8.	M.	Trauma to the left elbow in April, 1924.	Lower end of left humerus.	Treated for "rheumatism." Curettage May 15, 1924. Curettage of a recurrence November 25, 1924, without drainage. No infection of the wound.	Giant-cell tumor.	Giant-cell tumor.	Giant-cell tumor.	Well in May, 1925.	
XXIV.	2.	F.	Fracture of the right tibia in October, 1923.	Shaft of the right tibia.	Immobilization for sixteen weeks. Curettage on October 10, 1924, and March 12, 1925.	No diagnosis made.	No diagnosis made.	Giant-cell tumor.	Well in May, 1925.	
XXV.	36.	F.	Trauma to the right ankle in May, 1917.	Lower end of the right tibia.	Immobilization for "tuberculosis." Curettage in November, 1918. Curettage April 12, 1924.	Tuberculosis.	Tuberculosis.	Giant-cell tumor.	Well in May, 1925.	

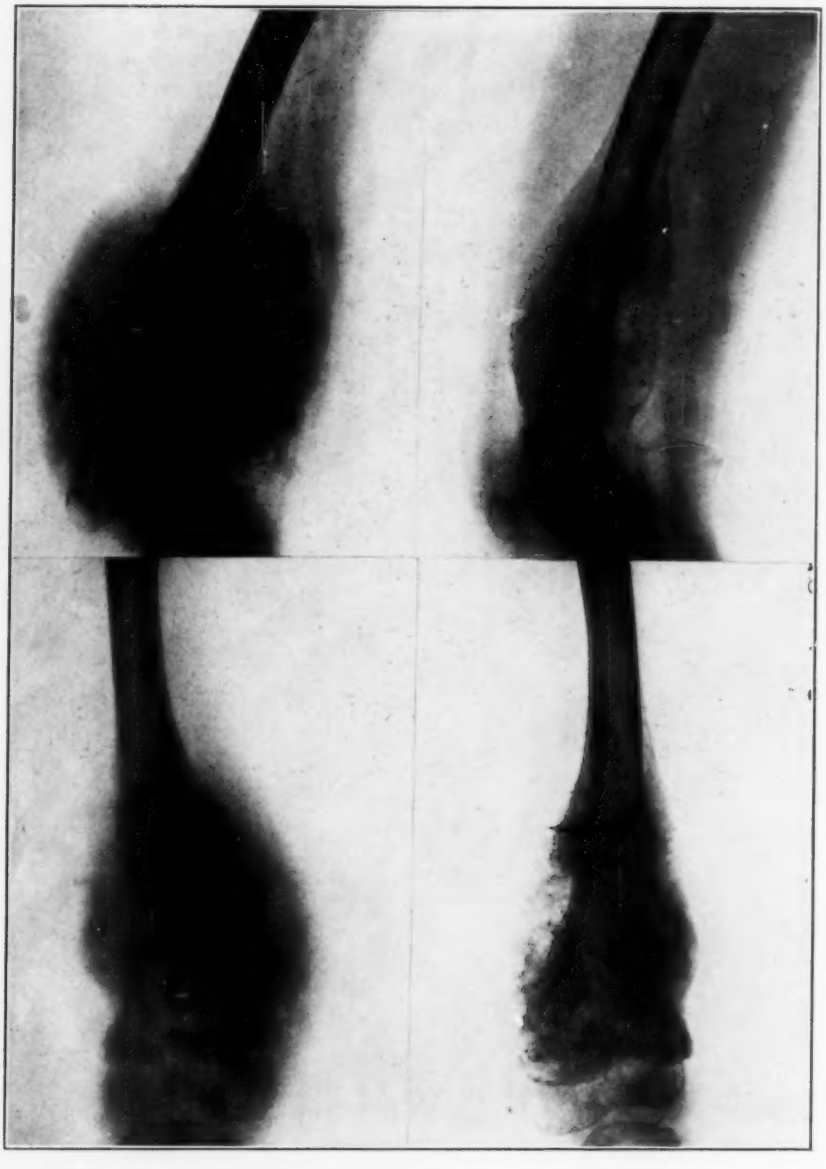


PLATE I

Roentgenograms of Case III. Left—before roentgen ray radiation; Right—after three high voltage radiations.

DIAGNOSIS

That Bloodgood's rules for diagnosis of bone tumors, based upon the age of the patient and the site of the tumor, are of only relative value may be concluded from the frequent exceptions to these rules. In this series there were three patients under fifteen years of age with a central osteogenic sarcoma of the shaft of a long bone.

PLATE II

Roentgenograms of Case IX. Reading from left to right: before the exploratory incision; four days after the exploratory incision (an iodoform pack in the operative wound); three weeks after the exploratory incision. Note the rapid growth of the tumor after the incision.

The diagnosis of sarcoma of bone rests upon a careful examination of the condition from all three angles, the clinical, roentgenologic, and pathologic. It is fundamentally wrong to emphasize the importance of any one of these three angles over the others. In two cases (Cases IX and XVII), in which the diagnosis of osteogenic sarcoma was made from the clinical and roentgenologic data, the pathologist reported "no diagnosis made" in one and "benign chondroma" in the other. On the other hand, there were cases where the histology alone decided the diagnosis.

There are two elements in the clinical history of sarcoma of bone that play a significant rôle in the majority of the cases and that have not been stressed emphatically enough in the literature. The first of these is pain.

Pain is the most characteristic symptom in sarcoma of bone. It is of a very severe, boring, cutting, and excruciating character, waking the patient from sleep. Pain was present in all but one case reported here. It is the earliest symptom in periosteal sarcomas. In central sarcomas

PLATE III

Roentgenograms of Case XIII. Left—two weeks after the responsible trauma. Right—four weeks after the trauma; taken on the preoperative day.

pain may appear at a later date, when the cortex of the bone is destroyed and the tumor mass encroaches upon the periosteum. Although a constant feature in bone sarcoma, pain is frequently intermittent in character, especially in the early stage. Pain of a rather dull character comes on immediately after trauma, lasts one to two weeks, disappears, and all that is left is perhaps a slight limp. From one to several months may pass and the patient begins to have pain again, but of the deep seated, excruciating character. Sometimes a new trauma occurs previous to this appearance of pain. Pain in sarcomas of bone felt by the patient during rest is important for differential diagnosis, since in other bone

conditions immobilization as a rule relieves this symptom. Two patients, however, had relief from pain after immobilization. The best explanation of the cause of pain in sarcomas of bone is pressure of the tumor mass from within the bone upon the periosteum. That pressure upon the periosteum, and not pressure upon nerves, as suggested by others, seems to be the cause may be concluded from the following facts. In periosteal and subperiosteal non-central sarcomas pain is a much earlier symptom. The spectacular, almost immediate, disappearance of pain after roentgen-treatment could hardly be explained by relief of pressure upon nerves,

PLATE IV

Roentgenograms of Case XIV. For histology see Plate IX.

but it is well in accord with its radical influence upon the rapidly growing tumor. Finally there is another bone condition—acute osteomyelitis with an accumulation of pus between the cortex and the periosteum—where pain is of similar severity. The pressure of the pus, which is under high tension, upon the highly sensitive periosteum causes the pain. Drainage here immediately relieves the agonizing pain.

Second in importance to the element of pain in the clinical history of a patient with a sarcoma of bone is trauma. There has been much discussion regarding the importance of trauma in the etiology of bone sarcoma. The strongest argument against the importance of trauma in sarcoma is the fact that sarcomas are rare after fractures. A careful review of histories of the cases reported here has shown definitely that there is a

history of trauma in 63 per cent. of the cases. It is usually absent in the histories of children, where a trauma is frequently denied because of fear of the parents and where it often passes unnoticed because of the gameness of the child. If children under twelve years of age are excluded

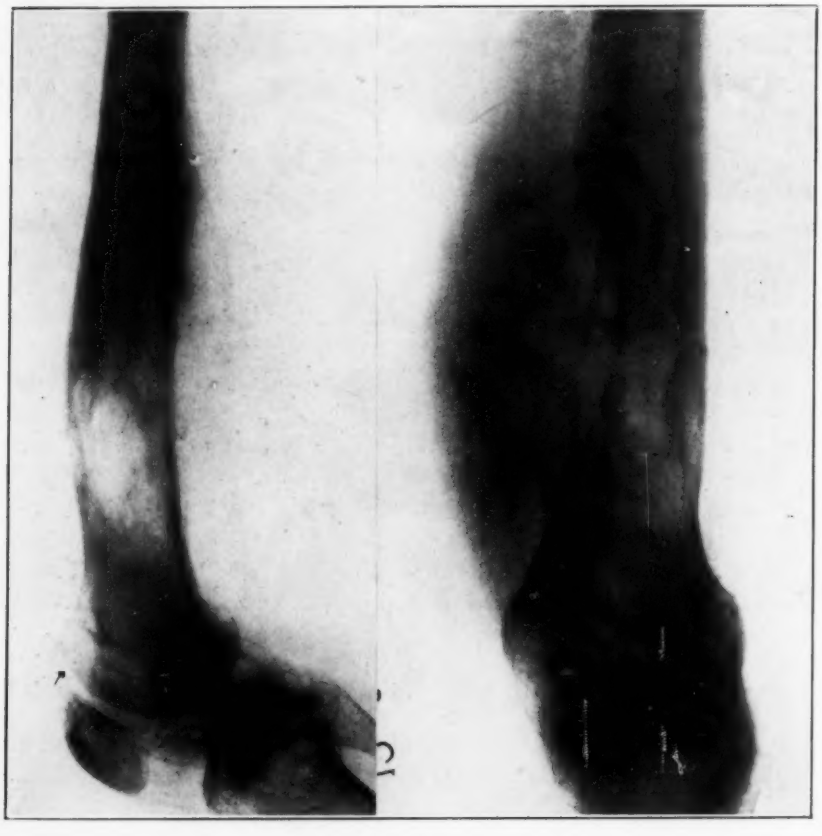


PLATE V

Roentgenograms of Case XV. Two weeks before the disarticulation.

from the present series trauma is present in 75 per cent. of the cases. That fractures, as a rule, are not followed by sarcoma is not an argument against the importance of trauma as an etiologic factor. As a matter of fact the character of trauma preceding sarcoma of bone is usually not a severe blow, but a slight trauma, frequently forgotten by the patient

until reminded by the appearance of pain. Apparently a direct trauma to the exact site of the tumor is not essential. In Case XIV trauma of the knee was followed by the appearance of sarcoma in the posterior aspect of the head of the tibia. Slight repeated traumatizing, which could hardly be qualified as a trauma in its usual sense, played a most distinct and important rôle in the etiology of Case II. The patient, a traveling salesman who drove a Ford, developed a sarcoma of the internal malleolus of the right leg. In his history the patient pointed out that in using

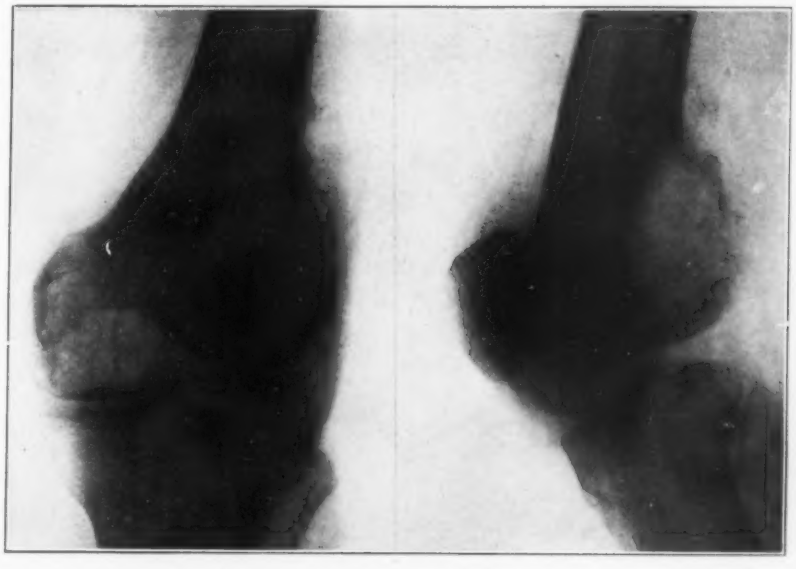


PLATE VI
Roentgenograms of Case XXII.

the brake the right foot frequently slipped down, laterally traumatizing the internal malleolus on the pedal.

ROENTGENOSCOPY

To read and correctly interpret a roentgenogram of a bone tumor is an art acquired only with wide experience. For this reason statistics showing the high or low percentage of cases correctly diagnosed roentgenoscopically are not indicative. The general tendency of a decade ago to overestimate the importance of a roentgenogram in the diagnosis of a bone tumor has been followed lately by a swing back towards underestimating

PLATE VII

Case XXIV. Roentgenograms taken (reading from left to right): on Feb. 25, 1924; on May 13, 1924; on Oct. 6, 1924; on Feb. 19, 1925; on March 6, 1925. For histology see Plate IX.

PLATE VIII

Roentgenograms of the inflammatory tumor in different stages of development. For histology see Plate IX.

its importance. This swing has been substantiated by authors because of the frequent errors in diagnosis if one depends on the roentgenogram alone. The same may be said of placing too much dependence on the clinical and even the pathologic evidence. There has been much argument

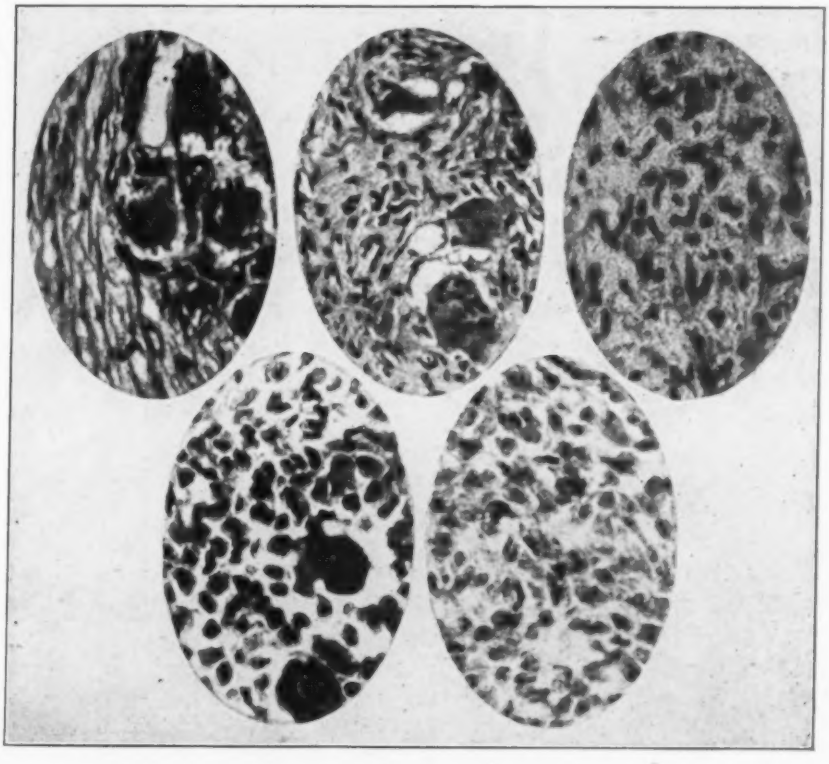


Plate IX

Photomicrographs. Reading from left to right: Top row: inflammatory tumor; Case XXIV; Case XXI. Bottom row: Case XIV, Case X.

as to the difficulty of differentiation in the roentgenogram between sarcoma and tuberculosis of bone. This is sometimes difficult to do clinically. A von Pirquet test in Case X,—a patient without evidence of tuberculosis elsewhere in the body,—gave a positive local, focal, and general reaction.

Much discredit given roentgenoscopy in the diagnosis of sarcoma of bone is due to set rules. Just two of these may be mentioned. That a

roentgenogram of a malignant bone tumor "is never definitely limited" is stated by Baetjer.[1] This rule has its exceptions. It depends greatly on the stage in which the sarcoma is seen (Case XIV). Just as perforation of the shell in giant-cell tumors is not a sign against this condition, so a definitely limited shadow in the roentgenogram is not a sign against osteogenic sarcoma. It is generally acknowledged that the most typical roentgenogram of an osteogenic sarcoma is that of a periosteal type. However, out of ten cases of periosteal and subperiosteal sarcomas the

FIG. 1
Roentgenogram of Case II.

classical picture was observed at the first examination in only three cases. In the majority of cases, especially in the well advanced and rapidly growing tumors, the fan-like structure may be very faint or invisible in the roentgenogram. Here the tumor mass is enlarging before formation of bone occurs. Roentgen treatment leads to a slowing down of the rate of growth and later the tumor casts its typical shadow (Case III).

HISTOLOGY

It is easy to understand why, when the differential diagnosis of bone tumors is uncertain by any single method, there exists a tendency to

"explore" the tumor and to shift the task of diagnosis to the pathologist. A biopsy of a bone tumor is still at present defended by most clinicians, although with certain limitations as to the procedure. It is significant

FIG. 2
Roentgenogram of Case IV.

that pathologists most experienced in bone tumors raised their voices against probatory incisions in instances where a sarcoma of bone is suspected. The main question presenting itself, "Is an exploratory incision of a bone sarcoma an innocent and therefore permissible procedure?" is best answered by an analysis of three points: (1) Is the pathologic diagnosis

absolutely always dependable? (2) Do all precautions offered by clinicians render an exploratory incision harmless? (3) Are there other procedures which may be substituted for the diagnostic incision?

As to the first point, the pathologic diagnosis is not always dependable

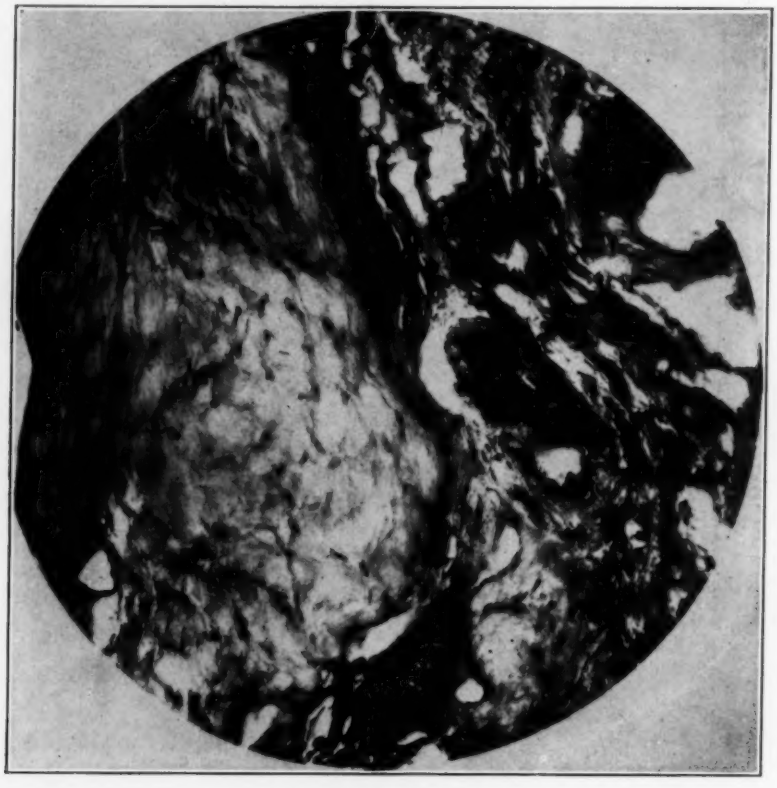


FIG. 3

Case IV. Photomicrograph of section taken from the primary tumor.

in examination of the small pieces of tumor usually removed in biopsies; sometimes even a diagnosis based on examination of numerous slides of a whole bone tumor may not be correct. Pathology is not an exact science and the personal equation of the pathologist counts greatly in the diagnosis.

The attempts of clinicians to neutralize the bad effect of a probatory incision by intensive cauterization of the operative incision really do not

offset altogether the bad effects of the exploration. The dangers of an exploratory incision are not merely the possibilities of dislodgement of metastases, but also that the surgical insult combined with the irritation by the escharotic used may increase the rate of growth of the tumor.

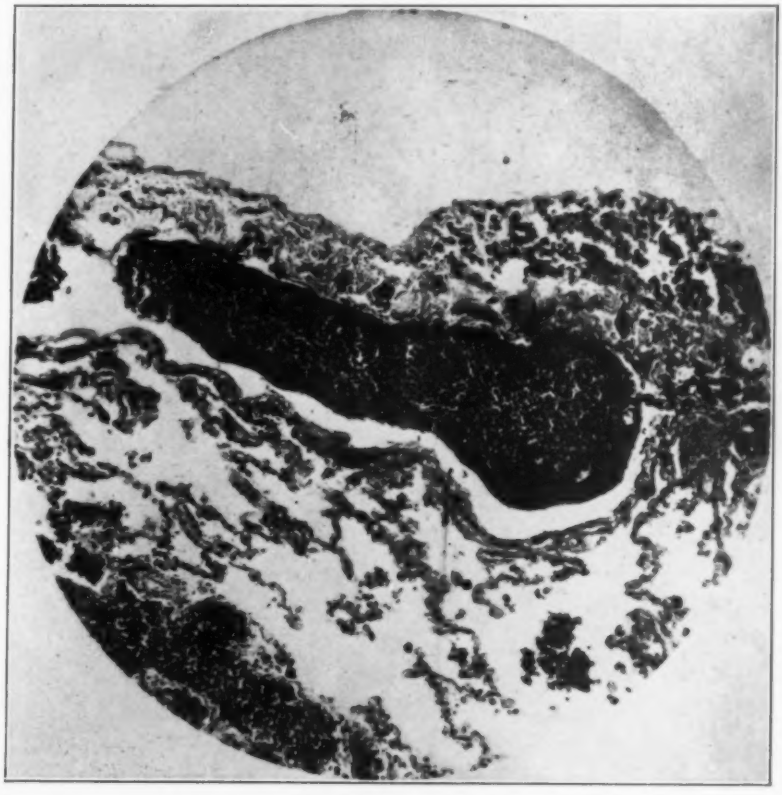


FIG. 4

Case IV. Photomicrograph of section taken from the pulmonary metastases.

In Case IX this is illustrated. Case XVII shows that not only a surgical incision, but even a plain accidental bloodless trauma, may stimulate the rate of growth of the tumor.

There is yet another method of diagnostic exploration practised. Two constrictors are used proximally to the tumor. The distal constrictor is to prevent dislodgment of metastases and the proximal is for an immediate

amputation should the tumor appear malignant. For the clinician well acquainted with gross pathology of bone tumors such an exploratory procedure may occasionally save a limb. However, the surgeon frequently is influenced in such cases by the decision of the pathologist after examination of a frozen section.

Bloodgood's rule: "Do not explore without a cautery" should be

FIG. 5
Roentgenogram of Case X. For histology see Plate IX.

changed to: "Do not explore unless immediate amputation is planned and can follow." To explore and then to institute conservative treatment is one of the most radical mistakes made. An exploratory incision in cases of supposed bone sarcoma where the high localization of the tumor prevents amputation or where an amputation is refused by the patient is frequently merely curiosity and is absolutely contraindicated (Cases V, VII, IX, XVI).

As to the above mentioned third point there is sufficient evidence to

justify the belief that roentgen radiation can successfully replace an exploratory incision in the majority of the cases. The cases in which roentgen radiation was used illustrate well this statement. No bone lesion reacts so rapidly to roentgen rays as do sarcomas of bone. The most agonizing

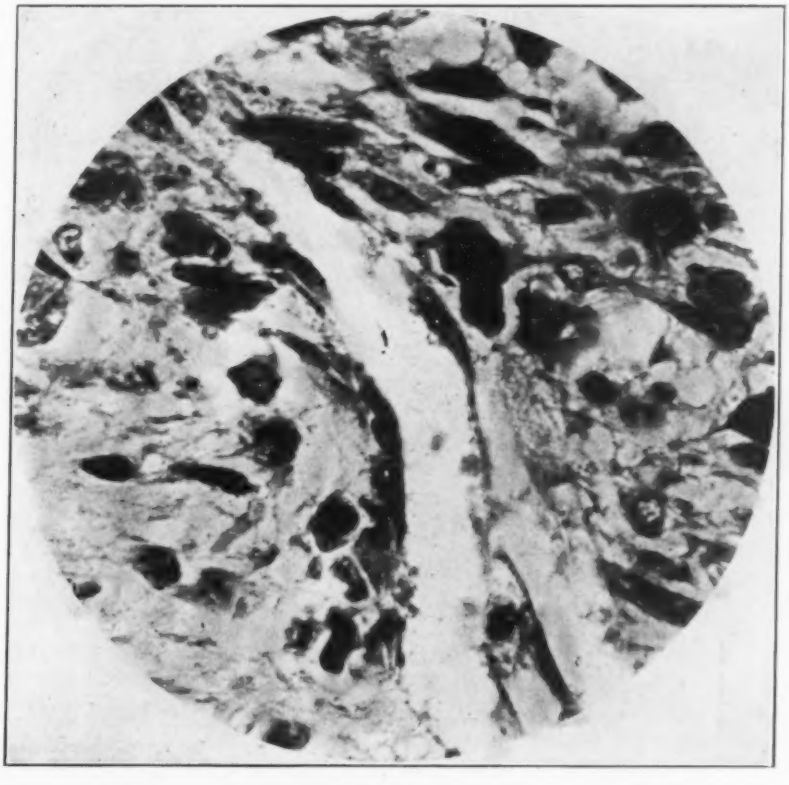


FIG. 6

Section from tumor of Case XIII. Note the intimate relation to the blood vessels.

constant pain frequently disappears after the first roentgen radiation. The rate of growth slows down remarkably so that an uncharacteristic and hazy shadow of a diffusely and rapidly growing periosteal sarcoma acquires all the ear marks of the most typical fan-like structure in a few days. The most rapid response to roentgen rays is noticed in cellular tumors. The response is somewhat retarded in sclerosing tumors. The relief obtained

from roentgen radiation is temporary. Pain often reappears after the lapse of a certain period of time after the roentgen radiation series. A new series of radiations will rapidly relieve the pain. However, each subsequent series of roentgen radiations is less effective than the preceding one. This suggests a bold question: Does this evident increase in resistance of the tumor cells to radiations speak for the infectious nature of sarcoma?

FIG. 7

Case XIV. Photograph of specimen. For histology see Plate IX.

PROGNOSIS

A definite prognosis as to life expectancy in sarcoma of bone is not possible because the natural history of the tumors which come under observation is usually changed by exploratory incisions, excisions, amputations, and radiations. Prognosis based solely upon the results of surgical treatment is questionable because many individual factors,—the type of the tumor, the stage of development of the tumor, surgical judgment in

FIG. 8
Case XV. Photograph of specimen.

selecting cases for treatment,—have a close bearing on the final result. In addition, the treatment or mistreatment preceding the final therapeutic measure employed is of the greatest importance. It is impossible to draw accurate conclusions as to the prognosis from the limited number of cases

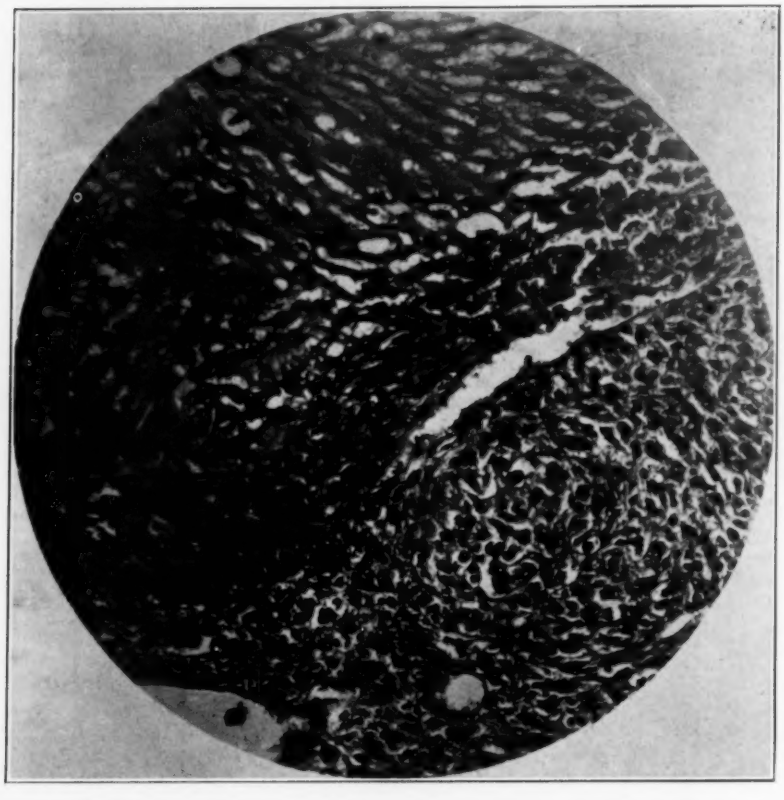


FIG. 9

Case XV. Photomicrograph of section taken from the primary tumor.

reported here. There are, however, a few moot points on which some of the cases may shed light.

As a whole it seems that the prognosis becomes worse with the increase in cellularity and vascularity of the tumor. Roentgen radiation is the more successful the less hyalinization and fibrosis is in the tumor, while radical surgical treatment is the less successful the more cellular the tumor.

As a matter of fact, highly cellular and vascular sarcomas treated surgically are fatal in an average of eleven months after the operative procedure. If encapsulated fibrosarcoma attached to the periosteum, which usually gives a fair prognosis following surgical treatment, is excluded from the present analysis, then sclerosing central sarcomas show the best prognosis.

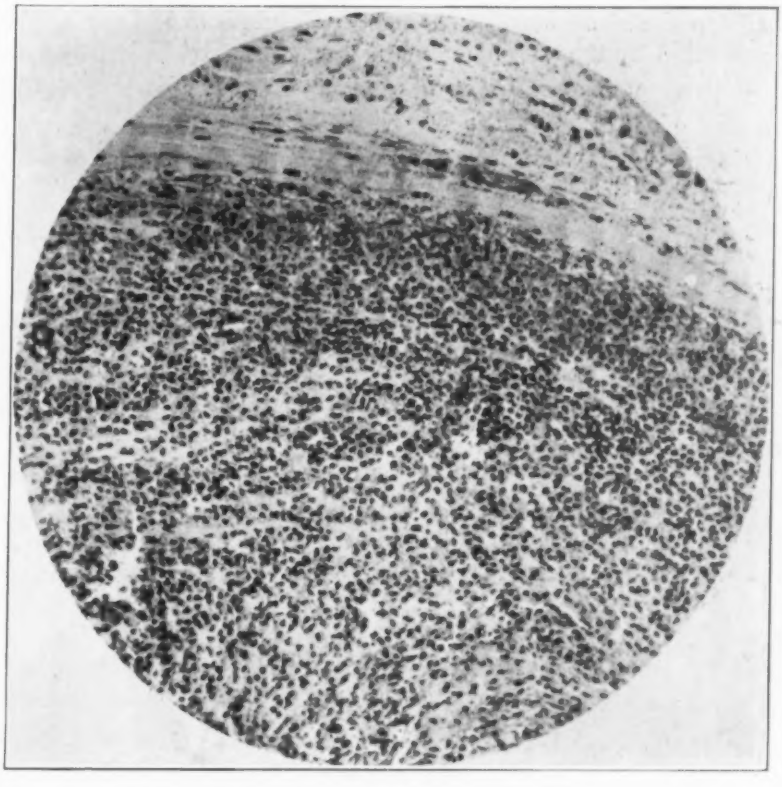


FIG. 10

Case XV. Photomicrograph of section taken from the pulmonary metastases.

However, the mixed types of sclerosing tumors with remaining cellular and vascular areas are more malignant. Necrosis, which is so frequently found in sarcomas with a rapidly advancing growth, speaks for a poor prognosis.

There is a tendency among pathologists to determine the degree of malignancy of a sarcoma of bone from the growth propensities of the

cellular elements alone — the irregularity and distortion of the nuclei, hyperchromatism, and tumor giant-cells. No rôle is to be ascribed to the supporting stroma. Codman doubts that the site of origin of a bone sarcoma, whether central or periosteal, has any influence on the prognosis. Facts seem to speak against these views. The most favorable prognosis is found in sclerosing osteogenic sarcomas which are mainly central in origin. On the other hand, a sarcoma with origin in the periosteum is earlier noticed by the patient on account of earlier subjective symptoms

FIG. 11

Case XVI. Photograph at admission to the University Hospital.

(pain). If the physician whom the patient consults would consider sarcoma as the first and not the last possibility, periosteal sarcoma perhaps would show a better prognosis.

Metastases are the main factor influencing the prognosis in sarcomas of bone. The abundancy of blood vessels in sarcomas with the spreading of metastases through the blood stream determines sarcoma to be far more malignant than carcinoma. While the metastatic involvement of the regional lymph nodes in carcinoma is the first sign that generalization of the malignant process has begun to take place, in sarcoma the generalization of the process may go on unnoticed until such a time as the most extensive pulmonary metastases have developed.

In the Cases V, VII, and XVI of the series reported here the regional lymph nodes showed metastatic involvement. The involvement of the lymph nodes seems to take place through the blood stream as it may be concluded from a histologic examination of these cases.

In sixteen of the seventeen fatal cases there were pathologic, clinical, or roentgenologic evidences of pulmonary metastases. On the whole it may be said that if signs of pulmonary metastases are present a rapid

FIG. 12
Roentgenogram of Case XVII.

fatal end is to be expected. It seems, however, to be different in sclerosing types of sarcoma. Years may pass before death from pulmonary metastases is reached. The frequent round-celled structure of the metastatic nodules in the lungs, even in cases of typical and far advanced sclerosing osteogenic sarcomas, suggests the conclusion that metastases occurred very early, during the undifferentiated stage of the primary tumor, but that they were very slow in progress (Case IV).

The general assumption, if pulmonary metastases are present, is that

no radical surgical treatment is indicated. However, there are cases where a palliative operation should be considered even in the presence of such metastases. Case XV illustrates this indication. Agonizing pain,

FIG. 13
Case XVII. Photograph of specimen.

which was relieved by roentgen treatment at previous admissions and which became uncontrollable, indicated a radical palliative measure—disarticulation of the extremity. There was every reason to believe that pulmonary metastases had already taken place, although there was no clinical or roentgenologic evidence of it. A few days after the surgical

operation, however, the patient expectorated some tissue which proved to be sarcomatous. By radical treatment in this case, although there is no chance for a cure, the patient has been relieved of unbearable pain.

FIG. 14

Roentgenogram of Case XXI. For histology see Plate IX.

The girl is now up and around on crutches, gaining in weight, happy, and free from mental and physical discomfort.

Generally speaking, surgical treatment in the large majority of sarcomas of bone is merely a palliative measure and is not the ideal treatment. Surgical treatment does not prevent metastases, nor does any other known method of treatment. A question presents itself: Will early recognition of bone sarcoma make possible a cure by surgical methods? Case

XIII seems to answer this question in the negative. The amputation of the thigh was done two weeks after the onset of symptoms of sarcoma of the fibula and four weeks after the responsible trauma. However, the amputation did not prevent metastases. "The nonoperative treatment of these diseases (sarcomas of bone) is a goal to be aimed at," says Ewing.[2] What can and must be done at the present day is not to do harm by the methods of diagnosis and palliative treatment. How very far we are yet from this may be judged from the history of Case XVI, which is by no means exceptional.

The Registry does excellent work. It is an original idea, perhaps the best collective way to study so comparatively rare a condition as sarcoma of bone. It is through the Registry that our knowledge of bone sarcoma today is broader than five years ago. However, diffusion of our limited knowledge among general practitioners upon whom it depends to direct the patient to the qualified surgeon is badly needed. Speaking on carcinoma of the stomach the late Kocher used to say: "The physician whom the patient consults first can do more than the whole long chain of specially trained surgeons who lead the patient on the true and hopeless way to the grave."

GIANT-CELL TUMORS

Since the days of the much quoted monograph of Nélaton to the present day there have been several changes in the surgeon's views upon this type of sarcoma. Through Bloodgood's immense influence treatment by amputation has given way in this country to the more conservative methods—resection or curettage. The belief that giant-cell tumors are always benign is so widely spread that many authors exclude them from their studies of sarcoma of bone. However, several cases of giant-cell tumors with metastases reported in this country and in Europe had such an enormous influence upon the average surgeon that a new swing is noticed, this time from the conservative treatment to radical surgery. The psychological factors involved are clear. The average surgeon does not care to take chances. It is much easier to amputate and forget than to be conservative and worry.

The most important question, "Are giant-cell tumors always benign?" has been recently answered in the negative by the majority of observers. Theoretically the possibility of a dislodgement of tumor cells in such a vascular and cellular tumor as a giant-cell tumor would seem natural, especially in such extensive surgical trauma as curettage. The cells are dislodged, but fail for some reasons unknown to multiply at their new site.

In some cases,— and fortunately these are exceedingly rare,—the dislodged cells grow in the same way as in a true osteogenic sarcoma. "Pathologists feel compelled to recognize various grades of malignancy in the group of giant-cell tumors," says Ewing,[3] one of the most experienced pathologists

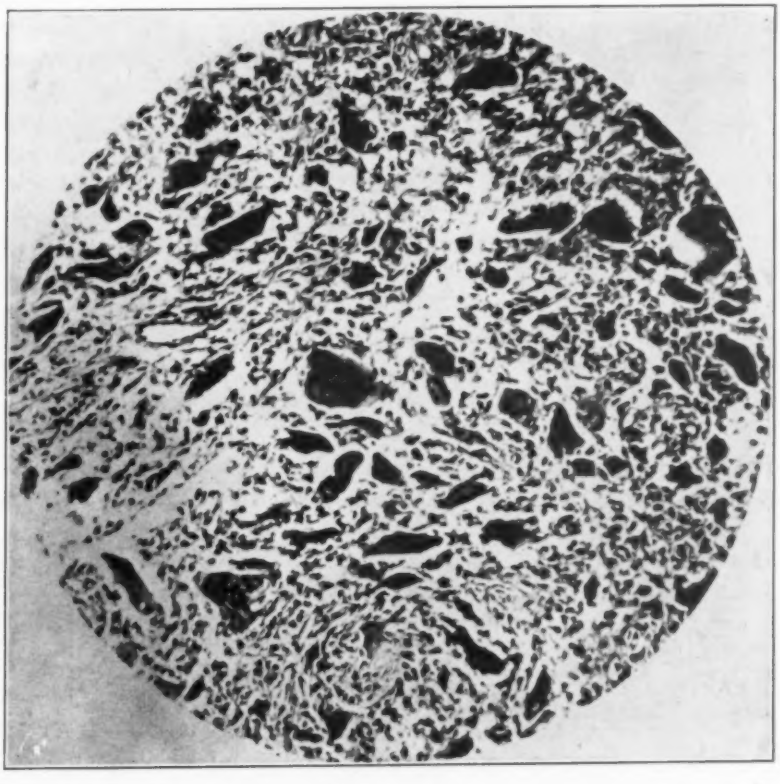


FIG. 15
Case XXII. Photomicrograph. Typical "giant-cell tumor."

and one of the most ardent opponents of including the giant-cell tumors in the class of malignant osteogenic sarcoma. A still more important question is: What are the signs of a malignant or borderline giant-cell tumor? The difficulty in answering this question is evident from the fact that there is still much to be learned of the histology of the usual giant-cell tumor. Histologically the two main features of a giant-cell

tumor are the foreign body giant-cells and the stroma consisting of spindle cells with vesicular nuclei. Which of these elements is to be chiefly considered? Since the foreign body giant-cells of endothelial origin may appear constantly in conditions in which erosion and disintegration of bone

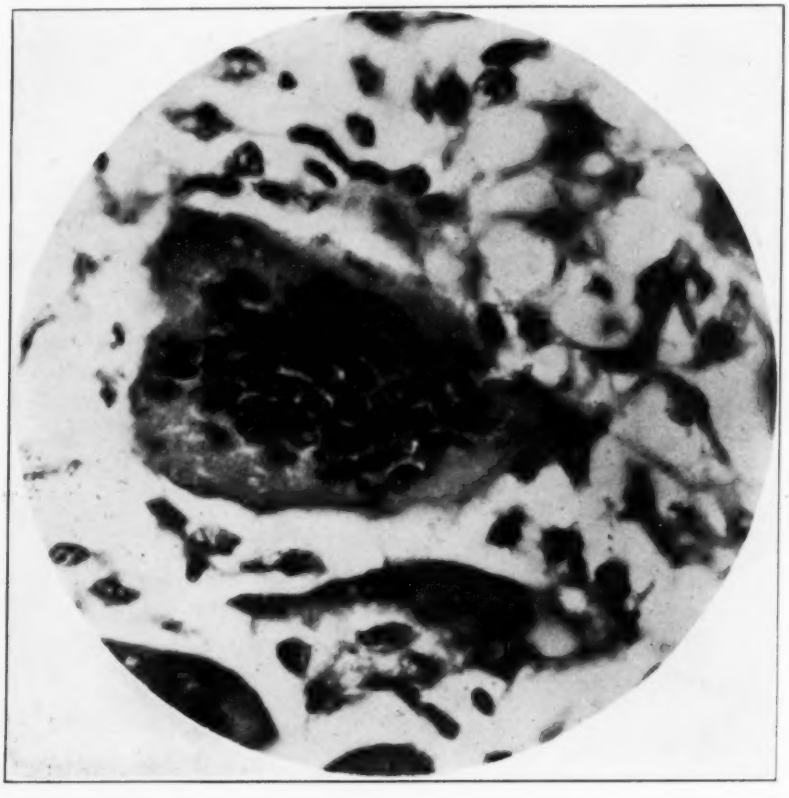


FIG. 16

Case XXII. High power of a typical foreign body giant-cell.

substance is going on it would seem probable that they are not an integral element of the giant-cell tumor. Ewing is of the opinion that in the diagnosis of giant-cell tumors we must consider more particularly the type of the supporting tumor tissue. Stewart and also Codman, on the other hand, maintain that the histologic diagnosis is based on the morphologic

character of the giant-cells, especially as regards their nuclei. According to these authors the giant-cells are not a fortuitous but a constant and integral element of the growth. Since foreign body giant-cells and spindle cells are encountered not infrequently in inflammatory conditions of bone on one hand and in true osteogenic sarcomas on the other, one sees how hazy the accepted pathologic picture of a giant-cell tumor is. On one hand the picture overlaps a structure of an inflammatory condition of bone with multiple foreign body giant-cells and on the other side it is in actual contact with a highly malignant sarcoma.

The great clinical importance of this question seems to justify an illustration of these difficulties by a comparative analysis of the histology of Cases X, XIV, XXI, XXIV, and a case of an inflammatory tumor of the os ischium. They all have in common the more or less definitely limited shadow in the roentgenogram. Four of these tumors are located in the same bone, in the tibia. In the first three the tumor was located in the head of the tibia. The main histologic features are:

In case of the inflammatory condition—pronounced vascularity, foreign body giant-cells in a scanty spindle celled stroma, absorption of old and production of new bone.

In Case XXIV—spindle cells with vesicular nuclei, foreign body giant-cells, hyalinization, and occasional central ossification.

In Case XXI—spindle cells with vesicular nuclei, few foreign body giant-cells, occasional ossification.

In Case XIV—spindle cells of the same character as in the preceding, few foreign body giant-cells, occasional central ossification.

In Case X—spindle cells of the same character, absence of foreign body giant-cells.

If the benignity of a giant-cell tumor is to be concluded from the character of the spindle cells of the stroma alone, then there is practically no difference between all these cases. Central ossification is found in all of them save the last. Few mitotic figures could be found in all of them. The main difference between all these tumors histologically is the absence of foreign body giant-cells in the last case, which ended fatally. Are then the foreign body giant-cells the chief, if not exclusive, sign of a benign giant-cell tumor? If so, then how can the inflammatory tumor be differentiated histologically from a true giant-cell tumor? In recurrences of giant-cell tumors after curettage fewer foreign body giant-cells are found than in the original tumor. The more differentiated type of tissue found, however, and cure after a repeated curettage, speaks definitely for the view that these changes in recurrences with the decrease in number of the

foreign body giant-cells are a sign of healing and not of malignant transformation due to surgical trauma.

There is a great deal yet to be learned about foreign body giant-cells. If these cells are the result of a reaction of endothelial elements to destruction of bone, then why should there be found fewer foreign body giant-cells in aggressive tumors, as the general opinion is? Case XXII, a typical giant-cell tumor, would seem to oppose this view. In this case the enormous destruction of the femur parallels the abundant number of foreign body giant-cells.

All these questions are presented merely to emphasize how little as yet we know about the true nature of giant-cell tumors.

ABSTRACT OF HISTORIES OF THE CASES MENTIONED IN TEXT

CASE II. A salesman, 26 years old, entered the University Hospital on June 18, 1920, with complaint of "an inflammation of the right ankle." In April, 1920, the patient began to have pain, which kept him awake at night. He gave a history of repeatedly traumatizing the internal malleolus of the right leg while using the brake of a Ford car. The clinical and roentgenologic diagnosis was leaning towards osteogenic sarcoma. This diagnosis was verified at the exploration with two constrictors proximal to the tumor: one on the leg to prevent dislodgment of metastases, and the other on the thigh for amputation. Immediate amputation of the thigh was done. The wound healed well. In December, 1920, pulmonary metastases were found and the patient died in May, 1921. Microscopic diagnosis: Cellular spindle cell periosteal sarcoma.

CASE III. A boy, five years old, suffered a trauma to the right knee in April, 1924. He favored his knee for about ten days after the trauma. In August, 1924, a biopsy was done by Dr. Spencer, St. Joseph, Mo., who sent the writer a stained section of the tissue removed. The section led to the diagnosis of a cellular spindle cell osteogenic sarcoma. Coley's toxins were given for a period of six weeks. The pain continued to increase and the patient entered the University Hospital on October 19, 1924. He was put on roentgen treatment. The pain disappeared entirely after the second radiation, and on October 31, 1924, the patient was feeling "fine" and was discharged. He was advised to return for further roentgen treatment. He was free of pain for four weeks, when he became worse, unable to return to the Hospital, and died April 4, 1925.

CASE IV. A laborer, 25 years old, entered the University Hospital on September 29 1922, with complaint of a tumor of the left hip. There was no history of trauma. In 1918, the patient first noticed a "small nodule" on the left hip. It was hard and fixed to the bone. It gradually increased in size and was the size of a turkey's egg at admission. Pain appeared in May, 1922. The pain was at first intermittent, but since July, 1922, it was constant and very severe, keeping the patient awake at night. The roentgenogram led to the diagnosis of a periosteal tumor. An excision of the tumor was done on October 9, 1922. The tumor was adherent to the great trochanter. It had a bony capsule, which was about one-eighth of an inch thick. The central portion of the tumor was made up of grayish masses of tissue slightly granular in appearance. Microscopic examination: Sclerosing periosteal sarcoma with cellular areas showing

myxomatous degeneration. On the eleventh postoperative day the patient suffered a stroke, with the clinical signs of a cerebral hemorrhage, and died on the twelfth postoperative day. At autopsy extensive pulmonary metastases were found. These metastases consisted of multiple nodules with a typical round-celled structure. No permission to open the skull was obtained.

Case V. A farmer, aged 29, entered the University Hospital on November 26, 1919, with complaint of pain and swelling in the right hip. Pain in the hip first came on during the last days of August, 1919, and kept the patient awake at night. Soon a swelling appeared. A physician gave him a "salve." Another physician diagnosed tuberculosis and "drained" the tumor with relief of pain. The swelling rapidly increased in size. After three weeks, "night pains" returned. The patient had lost forty-five pounds since August. At the Hospital the clinical diagnosis of tuberculosis was made, and the tumor curetted on November 29, 1919. The pathologic diagnosis "spindle cell sarcoma with numerous mitotic figures" was made from the tissue removed at the operation. The tumor grew very rapidly and the patient died January 4, 1920.

Case VII. In the middle of November, 1923, a boy, ten years old, began to complain of sharp night pain in the left shoulder. A swelling appeared about the end of November, 1923. The diagnosis of osteomyelitis was made and the tumor was curetted on January 3, 1924. Cellular subperiosteal osteogenic sarcoma was diagnosed microscopically and the patient was put on roentgen treatment. He died in December, 1924.

Case IX. A girl, 13 years old, entered the University Hospital on January 31, 1916. In November, 1915, she fell on the ice and hurt her right knee. She favored the right limb for just two days. In the latter part of November she began to have "shooting pain up and down the right thigh." It lasted for three days. In about two weeks she suffered a similar attack of pain. The pain lasted longer. She was treated for rheumatism by a physician. In January, 1916, attacks of pain became frequent. She was put in a cast, but since this aggravated the pain it was removed in two days. On January 20, 1916, the physician noticed a swelling of the right thigh. By this time the pain became a constant dull ache with very frequent attacks of deep-seated sharp pain like "pins and needles in the leg." At the Hospital the clinical and roentgen diagnosis was "probably sarcoma." On February 3, 1916, an exploratory incision was made. The operative report reads: "The periosteum was thick and raised from the bone by pus." An incision through "the periosteum brought two ounces of thick pus mixed with bone sand." The postoperative diagnosis was "cortical osteomyelitis of the femur." A rubber drain and an iodoform pack were left in the wound. The report of the pathologist after examination of a strip of periosteum removed was "no diagnosis made" and "no growth" in a culture of the pus. The pain rapidly became worse. The tumor was increasing at a rapidly advancing rate. The patient died with signs of pulmonary metastases on July 15, 1916. Microscopic diagnosis: Solid cellular subperiosteal sarcoma.

Case X. A tailor, 60 years old, entered the University Hospital on November 21, 1919, with complaint of pain in the right knee. In November, 1918, the patient first noticed some tenderness of the right knee. He limped for about three weeks. In the spring of 1919 the knee swelled. He was treated for "rheumatism"; later he was given "pain tablets" by his physician. At the Hospital no diagnosis was made clinically or roentgenoscopically. A von Pirquet test was followed by a strong focal, local (pain in

the knee), and general (temperature 99.8) reaction. An exploration of the knee joint with two constrictors as in Case II led to a diagnosis of osteogenic sarcoma from the gross pathology. An amputation of the thigh was done. The wound healed well. The patient died from pulmonary metastases in May, 1921. Microscopic examination revealed spindle cells with vesicular nuclei and a moderate number of mitotic figures.

Case XIII. A boy, 17 years old, while playing football the end of March, 1922, fell, and a playmate stepped on his left leg. The leg did not pain until two weeks later, when pain and a swelling of the fibula appeared. The roentgenoscopic diagnosis was osteogenic sarcoma of the fibula, and an amputation of the thigh was done on May 4, 1922. The wound healed well. The patient developed metastases in April, 1923, and died in May, 1923. Microscopic diagnosis: Solid cellular osteogenic sarcoma.

Case XIV. A girl, 14 years old, fell on a hardwood floor and hurt the right knee in May, 1924. She limped for a few days afterward. She noticed nothing until the middle of June, 1924, when the upper part of the right leg became "sore." In July, pain appeared and soon a swelling appeared in the popliteal space. She entered the University Hospital on December 19, 1924. The clinical and roentgenoscopic diagnosis was "probably sarcoma." An exploratory operation as in Case II was done. A tumor the size of a hen's egg was found arising from the posterior aspect of the head of the tibia. The intact bone shell, about half a centimeter thick, was cut and the central portion was found to consist of a reddish gray granular mass of tissue which could be readily scooped out with a curette. It was thought by the operating surgeon that the tumor was malignant, and a mid-thigh amputation was done immediately. The wound healed well. No recurrence to May 3, 1925. Microscopic examination: Spindle cells with vesicular nuclei; a few foreign body giant-cells and occasional central ossification. The pathologist's diagnosis was osteogenic sarcoma. The writer does not agree with this diagnosis. He thinks this to be a case of a border line giant-cell tumor.

Case XV. A girl, aged 12, entered the University Hospital on August 25, 1924. She felt well until June, 1924, when a dull deep-seated pain in the lower part of the left thigh appeared which kept her awake at night. She first saw a physician on August 14, 1924, who treated her for a "low grade rheumatism." A few days before admission to the University Hospital she noticed that the lower portion of the left thigh had enlarged. At the Hospital the clinical and roentgenoscopic diagnosis was "probably sarcoma of the femur." The patient was put on roentgen treatment. The pain disappeared after the fourth radiation. She was free of pain for fifteen days, when the severe pain returned. She received another series of roentgen radiations in October. This relieved her pain for ten days only. The pain became uncontrollable by roentgen radiation. Clinically and roentgenologically the chest was free of pulmonary metastases. Because of the constant agonizing pain, a disarticulation of the thigh was undertaken on December 5, 1924. On December 20, 1924, the patient expectorated several bean-sized pieces of tissue, which microscopically proved to be sarcomatous metastases to the lungs. The operative wound healed well and there was no clinical or roentgenologic evidence of a recurrence or metastases up to April 29, 1925. The patient is up on crutches, gaining weight. On dissection of the disarticulated limb a pathologic fracture of the lower third of the femur was found at the point where the tumor mass had perforated the bone shell. Microscopic diagnosis: Sclerosing central osteogenic sarcoma with cellular and vascular areas.

CASE XVI. In December, 1914, a butcher, 54 years old, fell on the left shoulder on a frozen sidewalk. The shoulder felt "numb" for some time and he had some pain in it. The shoulder soon swelled up. A physician treated him with hot dressings and he was not bothered until September, 1915, when the shoulder started swelling and paining again. Pain never left him after that. A physician gave him electric treatments in October and November. In December, 1915, he received a "special cure with mercury." The pain kept on as before, the swelling continued to enlarge, and the arm was swollen up to his neck. In September, 1917, a physician took the first roentgenogram and diagnosed a "dislocation" of the humerus. Under general anesthesia the physician "put the bone back in place." The pain became more severe and the swelling was rapidly enlarging. By that time the forearm and hand were swollen. In January and February, 1918, the shoulder was tapped by a physician six times and some bloody fluid removed. In February, 1918, an enlarged lymph node was removed from the axilla. The lymph node contained "two ounces of bloody fluid." He was admitted to the University Hospital in March, 1918. The roentgenoscopic diagnosis was osteogenic sarcoma. An exploratory incision was made in May, 1918. The microscopic examination showed a sclerosing type of osteogenic sarcoma. The patient died on September 2, 1918.

CASE XVII. A machinist, 34 years old, entered the University Hospital on November 10, 1918. In 1913, the patient, while plowing, stumbled and kicked himself in the left ankle. The ankle was "sore" for a week. One month later a small hard "bunch" appeared on the ankle. This grew slowly. In 1915, the patient had the tumor excised. He felt well until 1917, when he again bruised the same ankle. He had sharp pain until the summer of 1918, when a new swelling appeared. At the Hospital a local excision of the tumor was done on November 14, 1918. The tumor was found to be adherent to the old scar and arising from the tibia. The wound healed slowly. The pathologist's report was "benign chondroma." At the end of December, 1918, the patient began having excruciating pain. A new tumor mass appeared at the site of the one removed and grew rapidly. On February 4, 1919, an amputation of the leg was done. The wound healed well. The pathologic report was "mixed cell sarcoma." The patient died with evidence of pulmonary metastases on October 27, 1921. The microscopic examination of the tumor removed in November showed it to be an osteochondro-sarcoma. The tissue of the recurrence was found to be more cellular with numerous mitotic figures. The diagnosis of a sclerosing osteogenic sarcoma with abundant cellular and vascular areas was made.

CASE XXI. A boy, 15 years old, was admitted to the University Hospital on July 7, 1923, with a swelling of the upper third of the left leg. He first noticed the swelling on January 1, 1923. It was tender to the touch. Pain appeared and the swelling enlarged. The knee could not be straightened out after February, 1923. Osteopathic treatments were given in May, 1923. At admission to the Hospital an orange-sized tumor was found on the anterior aspect of the upper third of the left leg. On July 16, 1923, the tumor was explored. It was surrounded by a thin bony capsule. The central portion was made up of a gelatinous mass of granular tissue. This was lifted out with a curette and removed, leaving a clean bony cavity. It was drained with Dakin solution. Infection of the wound kept the patient in bed until the end of August, 1923. No recurrence was found up to April 29, 1925. Microscopically the tumor consisted of a spindle cellular stroma with foreign body giant-cells in limited numbers. Occasional central ossification was found.

CASE XXII. A minister, 52 years old, noticed in December, 1919, a "soreness" above the left knee. Soon he noticed a slight swelling in the popliteal region, which pained him. In March, 1920, he fell, twisting the knee in such a manner that a splinter of bone was broken off the left femur. He was kept in a cast for fourteen weeks, a roentgenogram was taken, and good union was pronounced. A dull ache at night continued. In July, 1920, the patient fell again, forcibly flexing the left knee, and he was forced to stay in bed for several months, since the swelling in the popliteal space increased in size. In the Fall of 1920 he was up on crutches. In January, 1921, he fell again, flexing forcibly the left knee and severe pain kept him in bed for six months. On October 5, 1921, he entered the University Hospital, where a diagnosis of a giant-cell tumor was made from the roentgenogram. He was operated upon on October 10, 1921. The external epicondyle and condyle of the left femur were replaced by reddish-purple vascular granular tissue encapsulated in a bony shell. Curettage with subsequent drainage led to an infection which kept the patient in bed until the end of May, 1922. On examination on April 24, 1925, the patient was found to be in good health with no evidence of a recurrence. Except for light valgus of the left knee no deformity of the extremity was seen. Microscopic examination: A typical structure of a giant-cell tumor with abundant foreign body giant-cells.

CASE XXIV. A girl, two years old, fractured the right tibia on October 28, 1923. This healed readily. On January 19, 1924, she fell again. A roentgenogram taken elsewhere showed a "green stick fracture" of the right tibia. She began having pain at that time. She entered the University Hospital on February 23, 1924. A roentgenogram showed angulation of the tibia and nonunion. The leg was kept in a cast for seventy-five days. During this time a growth developed at the point of the fracture, which continued to enlarge. The roentgenogram showed a multilocular cyst of the tibia. An operation was performed on October 10, 1924. The tumor was found to consist of jelly-like granulation tissue, very vascular, encapsulated in a thin bony shell, with bony trabeculae transversing it. The tissue was scooped out with a curette and the cavity drained with iodoform gauze. There was some infection of the wound, which healed, however, in one month. On reëxamination of the leg in March, 1925, a recurrent tumor was found, with the same roentgenologic picture. Again curettage was done. At this time the contents of the tumor were made up of dense fibrous tissue with islands of tumor tissue of a jelly-like appearance. Both the original and recurrent tumors consisted of a stroma of spindle cells with vesicular nuclei and foreign body giant-cells. The latter were considerably more frequent in the original tumor than in the recurrent. There was some central ossification noticed.

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DISCUSSION

DR. E. A. CODMAN, Boston: I want to say sincerely that Dr. Kolodny's paper is one of the most complete papers I have ever read on bone sarcoma. He has made two points in that paper which seem to me likely to be lost. One was the statement con-

cerning exploratory operation—"perhaps it is sometimes curiosity." I think that it is true that exploratory operation in a great majority of cases is merely from curiosity. Another thing, he said: "the average surgeon does not care to take a chance; it is much easier to amputate and forget than to be conservative and worry." I think those two things show Dr. Kolodny's understanding of the surgical attitude that exists all over the country.

Like President Wilson I have written down fourteen points which were suggested to me by Dr. Kolodny's paper, each of which I would like to spend a half-hour on, but I can only read these points themselves.

1. The use of the Registry cases is at the service of any earnest student. Dr. Kolodny's cases will be registered and his cases can be sent to you just as the other cases can be at your or his disposal.

2. When publishing, register your cases. Dr. Kolodny's paper will appear in the literature at some time and the slides, roentgenograms, and sections of his cases will be put in the Registry and will be available. Think what value Coley's first cases would be if we had slides of them. Thanks to his foresight in saving them we have many, but not all.

3. The diagnosis of osteomyelitis should always consider sarcoma, including Ewing's tumor. What the percentage of occurrence of osteomyelitis cases is compared to that of sarcoma I do not know, but I am sure the sarcoma figures are much greater than is usually supposed. The majority of cases of bone sarcoma are mistaken at first for osteomyelitis.

4. Trauma is a theoretical cause, but the trauma supposed to cause the tumor seldom does.

5. I believe osteogenic sarcoma to be unbalanced growth or repair. That is inferred by the frequency of occurrence in Paget's disease (14%) and by the great resemblance histologically and in gross to exuberant callus.

6. Do not explore until you have excellent roentgenograms and you are ready for action. Have X-ray prints and the container for the material ready to be sent to the Registry. Better still, register before exploring.

7. Histologically the finding of true tumor giant-cells in the tumor is the most reliable sign. However, a considerable percentage of malignant tumors do not show them. When present they are an almost certain indication of marked malignancy.

8. I object to the classification of central and periosteal tumors. I would like to spend an hour trying to obliterate Bloodgood's dictum which he has spread all over the profession regarding that point. I believe that true malignant tumors cannot be divided into central and periosteal because they are practically in every case both. It is a matter of proportion only. Naturally the medulla is usually the minor portion. I agree with his dictum that clearly central tumors which are not myeloma or metastases are probably benign.

9. The danger of metastasis is greater in sarcoma of bone than in any other malignant disease. I do not believe this is due to the character of the cells, but to the structure of the bone which holds the blood channels open, allowing the cells to be washed into the venous circulation.

10. Whenever there is glandular involvement or multiple bone lesions the tumor is probably a round-cell sarcoma of the Ewing type.

11. Bloodgood has convinced us that giant-cell tumor is a benign clinical lesion. The important thing is to educate the roentgenologist and the pathologist to recognize it without incision. I believe X-ray therapy to be the treatment of choice, without incision.

12. The absence of tumor vessels is a very striking point in the histology of giant-cell tumors. They may have capillaries or sinuses but no blood vessels with walls. They are present in all osteogenic sarcoma.

13. Preserve every bit of tissue removed at the primary operation.

14. Always register every case as soon as you suspect sarcoma. Let the Registrar share your inevitable errors in diagnosis and treatment with you. Help the Registry and let it help you.

DR. H. W. MEYERDING, Rochester, Minn.: This report on sarcomas of the long bones presents an excellent series of twenty-four patients, especially as individual cases are analyzed.

Three of the twenty-four patients with sarcoma of the shaft of the long bones were under fifteen years of age. In 109 cases of sarcoma of the long bones which I studied in 1921, there were ten patients under the age of ten, thirty-four from the ages of ten to twenty, making thirty-one per cent. of the total number of patients under the age of twenty, and seventy-five per cent. between the ages of ten and forty. It is difficult to lay down any set of rules on which to base a diagnosis based upon age alone, although the percentage of occurrence of various types of bone tumors may vary considerably as to age.

The vast majority of these tumors occur in the region of the knee. Seventy-seven per cent. of our cases were in the ower extremity, almost forty per cent. occurring in the femur.

Pain is the most constant symptom and varies according to the site and the periosseous structures involved. The pain is not always severe; at times it is mild and boring, but may be excruciating and intermittent in character.

About fifty-four per cent. of our patients give a positive history of trauma preceding tumor formation, and in many cases pain has been severe and definitely localized for some time previous to the observation of the tumor. It is interesting to note that in this particular series of twenty-four cases the percentage of trauma is still higher. The type of trauma in many cases in our experience has been a single severe blow, as for instance in the case of a mechanic who struck himself on the femur with a heavy hammer. This was followed immediately by pain; within a few weeks swelling was noticed, then a tumor formation, finally metastasis and death. In some instances the trauma has been directly to the area of the tumor formation, while in other cases it has been in the vicinity of the tumor formation.

I believe that the vast majority of bone tumors may be correctly diagnosed by an expert roentgenologist. There will be a small percentage of these tumors, however, which will baffle the most expert, and with the clinical and laboratory findings and history fail to permit accurate diagnosis. In such instances exploration under tourniquet and the opinion of a competent pathologist would be of immense value. The X-ray gives us our first knowledge of metastasis to the lungs, permitting diagnosis before clinical findings are obvious.

To recognize the site, size, origin, localization in, or invasion through osseous and periosseous structures, the absorption or production of bone, the condition of cortex and periosteum, and to interpret these findings correctly so as to differentiate the type of tumor, requires a very broad experience. Routine roentgenograms of the chest are advisable in all cases of suspected malignancy. Inflammatory lesions, tuberculosis, and syphilis must be kept in mind. It has been the author's experience to have patients referred with a diagnosis of sarcoma, in whom a low grade inflammatory lesion of bone was ultimately found.

Dr. Anatole Kolodny, Iowa City (closing the discussion): Dr. Bloodgood speaks about the surgical treatment of osteogenic sarcoma. This is the point I want to make: surgery in osteogenic is, as a rule, hopeless as far as cure goes. It is just a palliative measure to combat the intolerable pain. It is as palliative as X-ray treatment. Will surgery ever be able to cure sarcoma? I say, "No." I want to show two slides. This patient was hit in the right leg while playing football. The leg was amputated four weeks after the trauma and two weeks after the onset of pain. He died eight months later of pulmonary metastases. It was an osteogenic sarcoma. It is difficult to expect earlier diagnosis of osteogenic sarcoma. That is why Ewing's viewpoint that conservative treatment of osteogenic sarcoma is the ideal to be aimed at appeals to me so strongly.

AN EXPERIMENTAL STUDY OF THE TRANSPLANTATION OF THE NERVE SUPPLY OF MUSCLES

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In both peripheral and central nerve lesions the function of an extremity may be seriously interfered with by the permanent paralysis of a muscle or muscle group. In such cases it not infrequently happens that adjacent to the paralyzed muscles there are non-paralyzed muscles which may not only be useless but may actually impair function of the extremity. The advantage of the possible transfer of the power of all or part of these muscles in such a manner as to replace the paralyzed group has long been recognized.

Two methods of procedure have been used to accomplish this result. (1) Tendons of the non-paralyzed muscles have been united to tendons of the paralyzed muscles. (2) Attempts have been made to transplant the nerves of the active muscles to the paralyzed muscles.

The operation of tendon transplantation has proved of value in the re-establishment of function in partially paralyzed extremities. This method, however, can never be expected to restore completely the function of the paralyzed muscle, since the direction of pull of the transplanted tendon is always different from the original muscle pull. Also the muscle of which the tendon is transplanted is usually a muscle with insufficient power to replace the paralyzed group.

Several methods of transfer of nerve supply of non-paralyzed to paralyzed muscles have been described, the one most commonly used being some form of anastomosis between the active and the degenerated nerves. In 1903, Spiller and Frazier reported some recovery of power in a paralyzed muscle group in a case of poliomyelitis in which a portion of the proximal end of a nerve to an active muscle had been sutured to the distal end of the severed nerve to the paralyzed muscle group. The recovery of power in the paralyzed muscle took place in a few months. A. C. Taylor, in 1906, reported six cases of anastomosis between active hypoglossal and paralyzed facial nerves, with varying degrees of success.

Taylor sutured the distal end of the severed facial into a slit made in the hypoglossal. Some return of power in the muscles supplied by the facial nerve was noticed in thirteen months, and considerable voluntary control of the facial muscles in twenty-five months. Kennedy, in 1914, reported several experiments on dogs in which various methods of end-to-end suture of active to paralyzed motor nerves were employed, with recovery of power in the paralyzed muscles in from fifty-nine to ninety-six days. The return of muscle power in these experiments was determined by the ability of the animal to use the extremity. Erlacher and Heineke, in 1915, working independently, reported experiments in which a non-paralyzed nerve was implanted directly into a paralyzed muscle, with return of power and complete regeneration histologically of the entire neuro-motor mechanism in sixty days. These authors also report activating a paralyzed muscle by suturing its scarified surface to the scarified surface of a non-paralyzed muscle. In 1915, Steindler reported experimental and clinical studies of the direct implantation of an active nerve trunk into paralyzed muscle. This author isolated and severed a portion of the sciatic nerve of a dog, and the end of the central stump of this isolated portion was sutured into the substance of the vastus externus muscle. The vastus externus had been previously paralyzed by resecting the femoral nerve. He reports active contraction of the vastus externus on weak faradic stimulation of the transplanted nerve after ten weeks. Histological study showed the nerve branching between the muscle bundles and fibres and regeneration of the muscle fibres.

The object of this paper is to present the results of a series of experiments in nerve transplantation on animals by a method which seemed to offer a more direct contact between active and degenerated nerve fibres in muscles than the implantation of the nerve trunk directly into muscle, and one which presented fewer technical difficulties than the end-to-end suture of small nerve trunks.

Dogs were used in all experiments and experimental methods carried out as follows: Under anaesthesia both thighs were opened anteriorly, the rectus femoris muscles isolated, and their nerves resected. About four cm. of the nerve to each rectus muscle was removed. On the left side the rectus femoris muscle was divided transversely. A segment was then taken from the sartorius muscle at the entrance of its nerve and accurately sutured into the gap in the rectus femoris. On the right the rectus femoris muscle was divided transversely and resutured without the nerve-muscle transplant. The animals were all allowed to be about as soon as they had recovered from the anaesthetic.

In a second series of experiments the thigh was opened and the femoral nerve isolated to its point of exit from the abdomen. A lower abdominal incision was then made and the femoral nerve resected from its origin in the sacral plexus to its point of division in the thigh. Several weeks later the thigh was reopened, the muscles examined, and their response to faradic stimulation noted to make sure that paralysis was complete. The paralyzed rectus femoris muscle was divided and a segment of the adductor longus muscle brought to the front of the thigh and sutured into the defect in the rectus femoris muscle. The animals were allowed to use the leg as soon as they had recovered from the anaesthetic. In carrying the nerve muscle transplant to the front of the thigh it was necessary to isolate the obturator nerve to its foramen in the pelvis to avoid tension on the nerve. Some difficulty was experienced in accurately suturing the ends of the adductor longus segment to those of the rectus femoris muscle, on account of the difference in shape of the two muscles.

EXPERIMENT I. Dog No. 84. Operation October 6, 1921. Nerve-muscle transplant from sartorius into rectus femoris in left thigh as in Series I. Reoperated December 3, 1921. Thigh opened. Rectus femoris muscle not atrophied; good size (apparently normal). Transplanted block of muscle with nerves and vessels easily located. Stump of sartorius atrophied. Weak faradic stimulation of nerve caused contraction of rectus. Contraction was strong. It was most rapid and strongest in the muscle insert and immediately distal and proximal to it. Contraction definitely decreased in rapidity and strength on direct stimulation of the muscle away from transplant. Stimulation of stump of sartorius showed typical slow contraction of degeneration. Right rectus pale and smaller than left, and faradic stimulation gave slow reaction of degeneration. Dog sacrificed and entire rectus and portion of stump of sartorius removed for study. Microscopic examination of stained sections of the left rectus showed atrophy of the muscle bundles and some areas of degeneration where the muscle had been replaced by fibrous tissue. No active staining axis cylinders were seen in nerves distal to the suture line.

EXPERIMENT II. Dog No. 126. Operation October 7, 1921. Technique as in Series I. Re-operated December 17, 1921. Both thighs opened. Right rectus (nerve supply cut but no nerve-muscle transplant) atrophied, and faradic stimulation gave slow delayed contraction of degeneration. On left side block of transplant seemed well healed and entire muscle including transplanted block of good color. Electrical stimulation of transplanted nerve with weak currents or of muscle direct gave rapid, strong contracture. Stimulation of portion distal to transplant was not quite as rapid as when transplant was stimulated, but was distinctly contraction of innervated muscle. Dog sacrificed and both recti removed for study. Right rectus pale and atrophied and gave reaction of degeneration to faradic stimulation. Longitudinal sections of both rectus muscles and cross sections at various levels were studied microscopically. There was marked atrophy of the fibres of the right rectus, much less marked in the left, and areas of degeneration about the suture lines in both muscles. Nerves with actively staining axis cylinders were found in the muscle transplant in the left rectus and in the muscle proximal to the transplant. None were found distal to the transplant in the left, and none in any part of the right rectus muscle.

EXPERIMENT III. Dog No. 127. Operated October 15, 1921. Technique as in Series I. Re-operated January, 10, 1922. Left rectus showed only one suture line, the other apparently having given way, and transplanted block of muscle could not be identified. Portion distal to suture line pale and atrophied. Proximal portion much larger and better color. Weak faradic stimulation gave weak, slow contracture distal to suture line, and much more active proximal to it. Right rectus atrophied and gave typical slow contracture of degeneration.

EXPERIMENT IV. Dog No. 8. Operated October 18, 1921. Technique as in Series I. Re-operated January 14, 1922. Both right and left rectus muscles atrophied, and showed typical reaction of degeneration. Transplanted block in good position in left rectus.

EXPERIMENT V. Dog No. 115. Operated October 22, 1921. Technique employed in left thigh as in Series I. Dog became mangy and sick, and was sacrificed ninety days after transplant of block of sartorius into rectus femoris. Transplant in left rectus found hypertrophied proximally, but dwindling out toward distal suture line. Color of transplant good. Weak faradic stimulation of transplant gave quick, strong, active contraction, as did portion of rectus proximal to transplant, but distal portion of muscle did not respond to stimulation.

EXPERIMENT VI. Dog No. 41. Operated October 27, 1921. Femoral nerve resected as in Series II. Re-operated November 29, 1921. Rectus femoris isolated. Muscle atrophic and pale and gave slow reaction to faradic stimulation. A block of the adductor longus with nerve entering it from obturator was sutured into a transverse section made in rectus femoris. Re-operated January 20, 1922. Transplant identified in good position, but pale and atrophied. Faradic stimulation of transplant gave slow contraction of degeneration, as did stimulation of rectus muscle itself. Transplanted nerve followed from transplant to obturator foramen and was apparently intact. Stimulation of this nerve gave no response in muscle.

EXPERIMENT VII. Dog No. 147. Operated October 25, 1921. Femoral nerve resected as in Series II. Second operation December 8, 1921. Thigh opened. Quadriceps pale and flabby. Faradic stimulation of rectus femoris gave reaction of degeneration. Cross section of adductor longus contained nerve supply from obturator, transplanted into transverse defect in rectus femoris and sutured carefully in place and wound closed. January 7, 1922. Dog ran about well, very slight limp in operated leg. Considerable atrophy of thigh.

July 1, 1922. Re-operated. Right rectus femoris completely degenerated and apparently a mass of fibrous tissue. Gave slow reaction of degeneration on faradic stimulation. Obturator found ending in areolar tissue near rectus.

EXPERIMENT VIII. Dog No. 124. Operated November 29, 1921. Femoral nerve resected as in Series II. Second operation February 16, 1922. Quadriceps atrophied and pale and gave slow reaction to faradic stimulation. Block from adductor longus containing nerve supply from obturator transferred into cross section defect in rectus femoris and sutured anteriorly and posteriorly. Re-operated April 1, 1922. Small discharging sinus in suture line. Rectus femoris atrophic, and portion at site of transplant bound down by fibrous tissue (infection). Obturator nerve located but stimulation of this and of rectus muscle direct gave no response in muscle.

EXPERIMENT IX. Dog No. 160. Operated December 10, 1921. Femoral nerve resected as in Series II. Second operation January 9, 1922. Thigh flexors atrophied

and pale and responded slowly to faradic stimulation. Block from adductor longus containing nerve supply from obturator sutured into transverse defect in rectus femoris. Re-operated April 6, 1922. Rectus atrophied and pale and transplant had been largely replaced by fibrous tissue. Faradic stimulation of obturator nerve and transplant gave no reaction, and stimulation of rectus muscle distal and proximal to transplant gave slow reaction of degeneration. Dog sacrificed.

SUMMARY OF EXPERIMENTS I TO IX

In Experiments 1, 2, 3, 4, and 5, a nerve muscle transplant of sartorius muscle was sutured into a paralyzed rectus muscle in the left thigh. In Experiments 1 and 2 electrical stimulation definitely indicated neurotization of the rectus muscle, both proximal and distal to the nerve-muscle transplant. In these two experiments, stained sections of the muscle proximal and distal to the transplant showed some atrophy of the muscle fibres and areas of degeneration with fibrous tissue replacement about the suture lines. No actively staining axis cylinders were found distal to the transplant in either of these experiments. In Experiments 3 and 5 there was evidence of neurotization of the left rectus muscle proximal to the transplant but none in the distal portion. In these two experiments it was evident that the distal suture line had given way. Experiment 4 was entirely unsuccessful in showing any evidence of neurotization of any part of the left rectus femoris. In this experiment the transplanted block from the sartorius muscle was inactive.

In Experiments 1, 2, 3, 4, and 5 the nerve to the rectus muscle in the right thigh was cut at the same time and in the same manner as on the left, but no nerve-muscle transplant was done. In each of these experiments the right rectus muscle gave the typical reaction of degeneration on faradic stimulation of any portion of the muscle. Any active nerve reaction noted in the left rectus where nerve-muscle transplant was done was therefore assumed to be due to neurotization from the transplant, even though the reaction was in the portion proximal to the transplant.

In Experiments 6, 7, 8, and 9 the nerve-muscle transplant from the adductor longus was sutured into the rectus femoris. None of these experiments gave any evidence of neurotization of the paralyzed muscle. Injury to the obturator nerve in making it reach the front of the thigh and the dissimilarity in shape of the two muscles were considered the chief factors in failure of these experiments.

Another type of experiment was carried out on the rectus femoris muscle in an effort to throw some light on the failure of some of the previous experiments and the apparent success of others. In three experiments a

normal rectus femoris muscle was divided transversely distal to the entrance of its nerve and immediately sutured together. In two other experiments the nerve to the rectus femoris muscle was injected with alcohol. Several weeks later this muscle, which was paralyzed, and its fellow in the other thigh, which was not paralyzed, were divided transversely distal to the entrance of its nerve and immediately sutured together. This procedure was carried out in an effort to determine the result of muscle suture in a paralyzed muscle compared with suture of a non-paralyzed muscle, other conditions being the same.

EXPERIMENT X. Dog No. 147. Operated January 26, 1922. Left thigh opened and rectus femoris cut transversely below entrance of nerve and carefully resutured. July 1, 1922. Thigh reopened. Rectus muscle looked normal in color and of good size. Suture line hard to find. Faradic stimulation proximal and distal to suture line gave rapid, strong reaction of innervated muscle.

EXPERIMENT XI. Dog No. 160. Operated February 9, 1922. Left thigh opened and rectus femoris muscle divided transversely distal to entrance of nerve and carefully resutured. Re-operated April 6, 1922. Rectus femoris looked normal; suture line easily made out. Weak faradic stimulation proximal and distal to suture line and of nerve entering muscle, gave strong and rapid contraction of whole muscle. Rectus removed for study.

EXPERIMENT XII. Dog No. 124. Operated February 16, 1922. Left thigh opened, rectus femoris muscle divided transversely distal to entrance of nerve and resutured. Re-operated April 1, 1922. Portion of rectus distal to suture line atrophied and pale and faradic stimulation gave slow reaction of degeneration. Portion proximal to suture line was of good size and color, and response to faradic stimulation was rapid and strong. Stimulation of proximal portion did not cause contraction of distal portion. Muscle removed for study. On cross section the distal portion was principally fibrous and parts of the silk suture were found one cm. from the distal end of the active muscle.

EXPERIMENT XIII. Dog No. 167. Operated January 9, 1923. Right thigh opened and nerve to rectus femoris and sartorius injected with alcohol, where it branches from femoral. Re-operated March 5, 1923. Both thighs opened and rectus muscles isolated on each side. Muscle on right was atrophied and pale and felt soft and flabby compared to left. Faradic stimulation on right gave slow reaction of degeneration; on left reaction was active and strong. Each muscle divided transversely below point of entrance of nerve and carefully sutured together—ends in normal relation. Re-operated July 5, 1923. Both thighs opened, right rectus showed suture line plainly, and muscle proximal and distal to suture line looked normal. Faradic stimulation gave rapid active response proximal and distal to suture line. Left rectus small and stringy distal to suture line; felt like fibrous tissue. Faradic stimulation gave normal response proximal to suture line. No response distal to suture line.

EXPERIMENT XIV. Dog No. 126. Operated January 29, 1923. Right thigh opened and nerve to rectus femoris and sartorius injected with alcohol, at point of branching from femoral. March 22, 1923. Both thighs opened and rectus muscle isolated in either side. On right side muscles pale and atrophied compared to left. Faradic stimulation gave slow contraction on right; rapid and strong on left. Both

muscles divided transversely below the entrance of their nerves and carefully sutured together. Re-operated July 8, 1923. Rectus muscle on right larger, and suture line not as plainly seen as on left. Faradic stimulation gave rapid, strong response in both muscles, less active distal to suture line, and not so active on right where suture line had not held as well as on left. Right muscle removed for study.

SUMMARY OF EXPERIMENTS X TO XIV

In Experiments 10, 11, and 12 a normal rectus femoris muscle was divided transversely below the entrance of its nerve and immediately sutured together. In Experiments 10 and 11 neurotization of the portion of the muscle distal to the suture line had taken place after one hundred and sixty days and fifty-eight days respectively. Stimulation of the distal portion of these muscles with weak faradic currents showed active contractions. In Experiment 12 the suture line had apparently not held and the distal portion of the muscle had degenerated.

In Experiments 13 and 14 the rectus femoris muscles in both thighs were divided below the entrance of their nerves and sutured together immediately. In these experiments, however, the muscle on the right had been temporarily paralyzed by injecting its nerve with alcohol. In Experiment 13 the distal portion of the muscle that was paralyzed at the time it was divided and sutured gave evidence of active neurotization. In the other side the portion distal to the suture line had degenerated. In Experiment 14 the muscles on both sides showed evidence of neurotization of their distal portions.

In these experiments as well as in the earlier ones, reneurotization of the paralyzed portion of the muscle seemed to depend on the accuracy with which it was held in approximation to the non-paralyzed muscle. Temporarily paralyzing the muscle by injecting its nerve with alcohol previous to its division and suture did not prevent neurotization from taking place.

DISCUSSION

The conclusion was drawn from summing up the entire series of experiments that it is possible to reneurotize a paralyzed muscle by transplanting a block of active muscle containing its nerve supply into the paralyzed muscle, but the technical difficulties are so great that considerable doubt is thrown on its practical application. Thorough suture of the muscles was attempted in all experiments, using mattress stay sutures and whipping the edges of the muscle ends together with anterior and posterior rows of continuous fine silk. Better results might have been

obtained had the extremity been immobilized in plaster-of-Paris for a time to prevent undue strain on the freshly sutured muscle.

Several points were brought out in the work that are considered of value, both in future investigative work and in practical surgery. It was noticed that dogs in which sartorius muscle had been resected and the rectus femoris paralyzed, got about perfectly normally after a few weeks, showing no limp whatever in walking. Experiments, the results of which were determined by the ability of the animal to use the extremity, would therefore seem unreliable.

The need of practising the utmost care in resuturing muscles which have been cut across during any type of surgical operation was clearly demonstrated. A muscle may not be cut transversely with the assurance that it will recover its function. If, however, it becomes necessary to cut muscles during a surgical procedure, care in accurately approximating their ends and thoroughness in suturing them gives a very good chance for their ultimate function.

I would like to express to Dr. Barney Brooks, under whose direction the work was carried out, my appreciation for his help and suggestions.

DISCUSSION

Dr. William S. Baer, Baltimore: In the first place I desire to congratulate Dr. Stewart on the painstaking series of experiments which he has performed. His work allows a gleam of hope in the direction of making nerve transplantations in anterior poliomyelitis a possibility.

We have all been disappointed heretofore in our results of nerve transplantations in cases of infantile paralysis. There seem to be certain conditions within the nerve sheath in anterior poliomyelitis which do not allow regeneration. I have done a large series of experiments in cases of paralysis of the lower extremities in which the sciatic nerve was cut and revolved on itself. The immediate result, of course, was a complete paralysis of all the muscles in the leg which was enervated by the nerve. The ultimate result was a recovery of muscular power of all the muscles which had been normal previous to the operation, but did not result in bringing back any muscles which were paralyzed by the anterior poliomyelitis.

I say, therefore, if this new transplantation of muscles obtaining the end organs of the motor nerves can be done, we may have a new method of resuscitating paralyzed muscles by this form of nerve transplantation.

Dr. Nathaniel Allison, Boston: Dr. Stewart's very careful experiments seem to me to show the proper spirit of experimentation. His observations on the healing of muscles after section which came out of this experimental work are a contribution. I think very few of us have thought much about what happens to muscle when we cut it partly across or cut it entirely across. In the experiments done here he has shown that that is a serious injury and one from which the muscle distally may not recover at all. If we, knowing this, cut muscles we are at least aware of what we are doing, and we may take better precautions to make sure of the healing of the cut muscle.

Dr. Leo Mayer, New York City: There are a number of points I would like to talk about. In the first place regarding nerve transplantation in poliomyelitis: In the year 1910 Stoffel of Mannheim published a case in which the circumflex nerve was implanted into the brachial plexus for a paralysis of the deltoid, with an excellent result. This seemed such an astounding piece of work that I made a personal trip to Stoffel to question him about it. He told me he had been misled in his observations. He found out subsequently that the paralysis of the deltoid was only a pseudo-paralysis, and he found by actual dissection that the nerve transplanted had nothing to do with the subsequent result which he had published. Spitzy, when I talked with him, bore out Dr. Baer's observation that in infantile paralysis the results of nerve transplantation are not successful. Both Stoffel and Spitzy have done more experimental work than any two Germans. Dr. Erlanger has had considerable experience. I conducted experiments by transplanting the nerve directly into the muscle and then making microscopic examinations. I found there was a little straying of the nerve fibers into the muscle, such as to make definite neurotization of the muscle possible; in other words, we got microscopic neurotization but not enough for practical purposes.

The third point is the question of muscle regeneration after its division. I have recently had occasion to see three cases in which the muscle was completely divided. Two were cases of traumatic rupture of the quadriceps, in both of which operation and suture was done within two days and two weeks after the tear. In both cases there was complete recovery of the divided muscle. In another case, in which the musculospiral was very extensively involved and a complete division of the triceps muscle had to be done in order to expose the nerve, there was a complete regeneration of the muscle despite its complete division.

Dr. J. J. Nutt, New York City: I would like to say a word about the grafting of a sound muscle to a paralyzed muscle. In experimenting with dogs this is very encouraging. In one case we could trace the nerve growing from the normal muscle into the one paralyzed, and even the function of an end plate. These muscles are not the same as the paralyzed muscles from poliomyelitis where degeneration has taken place by the time operation is considered. In many cases we get a little recovery, but I do not think we get full return of power except in early cases.

Dr. J. Edgar Stewart, St. Louis (closing the discussion): I would like to thank the gentlemen for their discussion. I have nothing further to add.

AN UNUSUAL CASE OF INFECTION OF THE SPINE

BY LEO MAYER, M.D., NEW YORK

"An angular kyphosis is due to a destructive process of the vertebral body." This teaching was hammered into my head so thoroughly when I was a medical student that it seemed to me as axiomatic as a mathematical proposition. It was taught that the destructive process was tuberculosis in the large majority of cases, syphilis or malignant disease in a smaller percentage. With this teaching in mind I found it particularly difficult to explain the findings in a most unusual case which came under my observation during the year 1917.

The patient was a girl of five years. The previous history was insignificant except for a purulent mastoiditis six months before. The significant feature at the time of my first examination (November 22, 1917) was the presence of an angular kyphos at the level of the first lumbar vertebra (Fig. 1). The kyphos resembled in all clinical aspects that found in Pott's disease. There was typical tenderness in the left iliac fossa and spasm of the left psoas muscle. There was bilateral ankle clonus and marked exaggeration of the knee jerks. The local examination left so little room for conjecture that I should at once have made a diagnosis of Pott's disease had it not been for two disturbing clinical facts: first, the peculiar septic temperature, which had risen occasionally as high as 106°; second, the blood count, white cells 16,000, polynuclears 80. The unusual nature of the spinal disease was further evidenced by the roentgenogram. This showed an angular kyphos, the knuckle corresponding to the spinous process of the first lumbar vertebra. There was, however, no narrowing of the anterior portion of the bodies of the vertebra nor other evidence of bone destruction. The only change seen was a narrowing of the anterior portion of the intervertebral spaces between the first lumbar and the adjacent vertebrae. This caused the prominence of the first lumbar spinous process. (See Fig. 2.)

The patient was immobilized at once on a Bradford frame. Within two weeks the kyphos had almost disappeared. At this time the patient developed some indefinite lung signs and it seemed advisable to remove the child from the frame. Within twenty-four hours the kyphos reappeared, only to disappear again as soon as the child was replaced on the frame.

The temperature meanwhile had continued its septic course. Three blood cultures had been reported negative.

Shortly after my first observation of the spinal abnormality the patient complained of pain in the right hand. Examination showed a slight general swelling and marked tenderness of the proximal phalanx of the index finger. A splint was applied. Within two days the swelling and tenderness entirely disappeared. Two weeks later there was a swelling of the left knee and a week later the right wrist became puffy and painful.

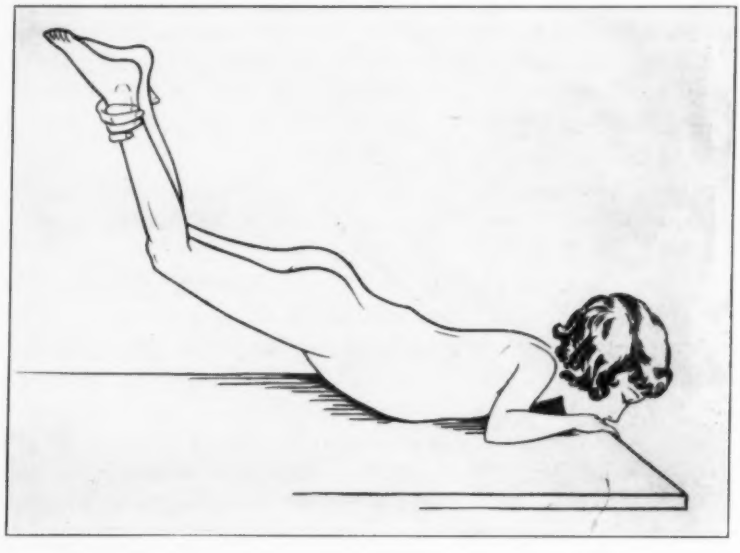

FIG. 1

This illustrates the deformity of the patient's spine when first examined and the spasm of the spinal muscles.

It was at this juncture, six weeks after the onset of the illness, that Dr. Bradford was called from Boston, to see the patient. He concurred in the view that there was a lesion of the first lumbar vertebra. He based this view on the presence of the angular kyphos and on the signs of irritation of the cortical spinal tracts evidenced by the increased reflexes. The nature of the lesion was, however, as puzzling to him as it had been to me. The puffiness of wrist and knee disappeared spontaneously. For the next three or four weeks no changes occurred, but on January 2, a swelling developed to the left of the first and second lumbar spines. This

swelling was exceedingly tender on deep pressure and gave evidences of deep fluctuation. Although it was strongly suggestive of abscess, incision was postponed for two days. Within that time the swelling became mark-

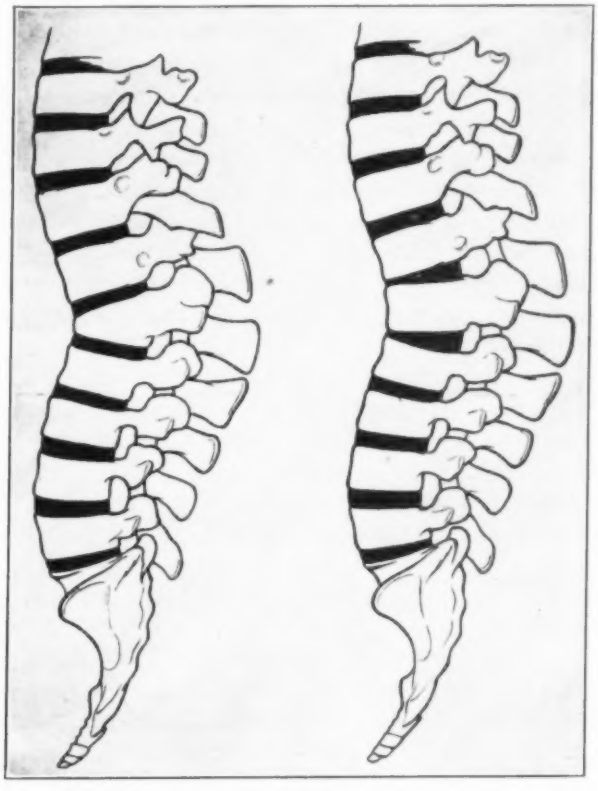

FIG. 2

These two diagrammatic drawings illustrate the manner in which a kyphos can be caused either by a destruction of the body of the vertebra or by a narrowing of the anterior portion of the intervertebral discs. On the left is shown a typical picture of an early Pott's disease, on the right the conditions shown by the roentgenogram of the patient.

edly less and soon it entirely disappeared. In other words, it behaved very much as had the index finger, the right wrist, and the left knee.

On January 6 the blood showed the streptococcus viridans in anaerobic culture. This finding made the diagnosis clear: we were dealing with a

case of streptococcus septicaemia in which the bone foci were the predominating local manifestations. The explanation of the kyphos, however, still remained unsolved, since at no time had there been any roentgenologic evidence of the bone destruction which according to all previous conceptions was the cause of the gibbus. On January 19 there appeared a red, tender, infiltrated area over the left tibia, about one and a half inches in diameter. The roentgenogram showed no abnormality of the bone. Within two days this also entirely disappeared. The patient had a similar swelling behind the left trochanter, which vanished like the others in a few days. The temperature gradually became lower and the kyphos disappeared. The patient was given an autogenous vaccine prepared from the cultures of the streptococcus viridans. Despite temporary improvement the child became weaker and had to be given repeated blood transfusions. The blood cultures remained positive. Other additional bone foci manifested themselves over the sacrum, the fifth rib, and the right elbow. These also disappeared spontaneously. The child gradually grew more septic, in June the temperature again rose to 106, and death occurred in July, with symptoms suggestive of an infection of the liver. No autopsy was permitted.

From the orthopaedic point of view this case is of significance for two reasons: first because of the unusual bone lesions caused by the streptococcus viridans. The other streptococci and all the staphylococci produce purulent bone inflammation. The streptococcus viridans seems to be an exception to this rule. In the patient under consideration there were at least eight bone lesions, none of which caused actual pus formation. In two cases of streptococcus viridans infection of which Dr. E. Libman of the Mt. Sinai Hospital gave me a personal report, no pus was found when the bones were exposed at time of operation. In the one instance, an infection of the ilium, the bone showed microscopic evidences of inflammation but no breaking down such as occurs during a pyogenic process. The therapeutic significance of this fact needs no further comment.

The second unusual feature of this case was the kyphos formation without evidences of bone destruction. Shortly after Dr. Bradford's consultation he wrote me with regard to this case: "I have always supposed that the cause (of a kyphos) was attitudinal combined with supra-imposed weight; in other words, that there would be no kyphos in a quadruped." This view coinciding closely with the classical teaching seemed to be refuted by the case under consideration. Here a kyphos developed while the patient was recumbent so that there was no supra-imposed weight nor was there any destruction of the bone such as produces a kyphos in Pott's disease or in malignant neoplasms. There was unquestionably a strepto-

coccus infection of the first lumbar and probably of the adjacent vertebrae. Judging by the lesions of the phalanges, tibia, and ribs, the vertebrae and the surrounding tissues must have undergone acute inflammation without, however, forming pus.

To explain the development of the kyphos under these unusual circumstances, I studied the literature of osteomyelitis of the spine. I found that in ten cases out of eighty-four collected from the literature, a gibbus had

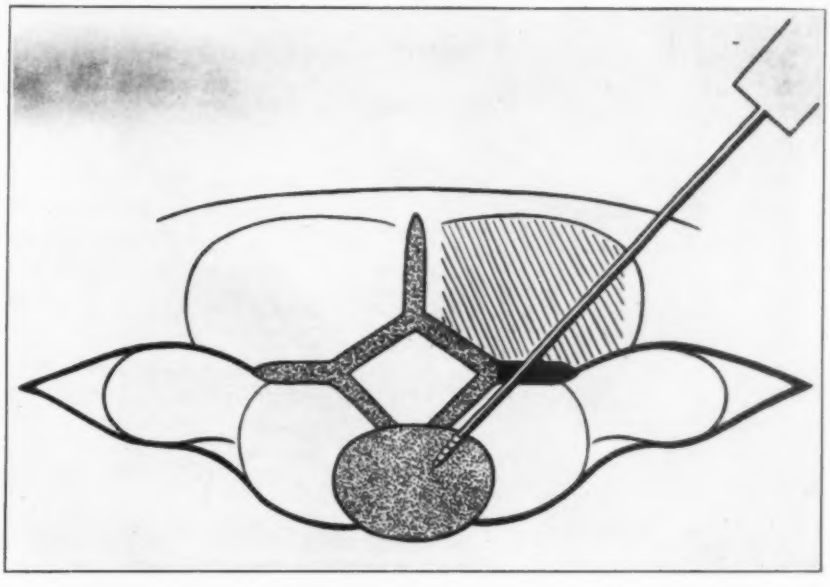

FIG. 3

This illustrates a simple method of operative approach suitable for draining the bodies of the vertebra. The erector spinae muscles (shaded) are retracted upward, exposing the transverse process (black). This is resected, the psoas muscle is stripped away from the pedicles, and the body of the bone is then readily accessible.

occurred; most of the observations, however, seemed to indicate that this was due to softening of the body of the vertebra. Conditions pathologically more closely resembling those in my patient are reported by Murphy in an article on Typhoid Spine. He found that deformity (a mild kyphos) developed in seventeen out of fifty-nine typhoid spines which he had studied. In three of the seventeen the deformity persisted after the acute process had subsided. In none of these cases was there actual destruction of the bone. There was, however, a definite disappearance of the intervertebral

discs, in some cases with a synostosis of the vertebral bodies above and below. Murphy explained the formation of the kyphos on the basis of a softening of the intervertebral discs. In my patient this explanation

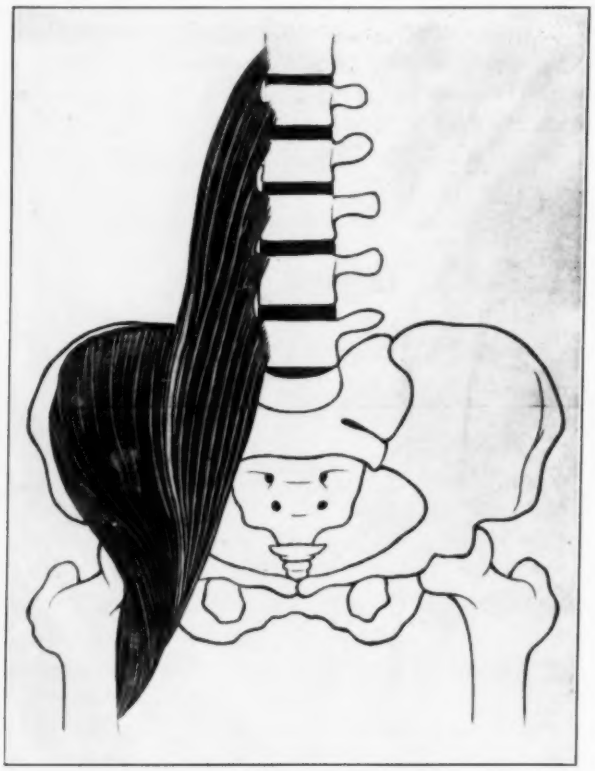

FIG. 4

Semidiagrammatic drawing of the right psoas muscle. This muscle was probably responsible for the narrowing of the intervertebral spaces in the case described. The action of this muscle with the thigh fixed would be to draw the bodies of the vertebrae closer together anteriorly. This muscle at the time of examination showed distinct spasm evidently due to a reflex irritation at the site of the lesion in the first lumbar vertebra.

would also seem probable since the change in the axis of the spine occurred not through any alteration in the shape of the bone itself but because of a narrowing of the intervertebral spaces in their anterior portion. Why the narrowing should occur anteriorly and not posteriorly is not explained by

Murphy. It seems, however, probable to me that in the lumbar region this could easily be explained by the contraction of the psoas muscle (Fig. 4). This was quite definitely present in my patient, particularly on the left side. As the psoas spasm disappeared the kyphos also became less. Whether under similar circumstances a kyphos would have developed in the dorsal region of the spine it is impossible to state.

SUMMARY

The clinical study of this case forces us to amend the current conception of the cause of an angular kyphos. A kyphos is not necessarily produced by a change in the shape of the vertebral bodies. It may also be caused by an inflammatory lesion of the bone, which, without resulting in actual bone destruction, seems to favor a softening of the intervertebral discs and a consequent deviation of the spinal bodies from the normal alignment. In the lumbar region the kyphosis could be produced by a spasm of the psoas muscle, which, taking its origin from the lateral process, would cause a buckling of the spine demonstrable in the roentgenogram by a narrowing of the anterior portion of the intervertebral spaces. In the case studied, the inflammatory lesion was due to the streptococcus viridans, which in this, as well as in other reported cases, causes bone inflammation without pus formation.

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DISCUSSION

DR. LORING T. SWAIM, Boston: This paper is extremely interesting, and I think we are indebted to Dr. Mayer for presenting it. We know so little about the streptococcus viridans and its action in the human body that we appreciate any information we can get as to its action in a case like this, where it apparently produced quick results. Very many viridans infections are of low grade and do not produce enough symptoms to enable us to verify the infection. For instance, the streptococcus viridans is very apt not to produce muscle spasms which we get with other infections. In my experience it is very apt to attack the tendon sheaths and attachments to muscles as well as the periosteum. I think, therefore, if we can verify a streptococcus viridans infection we will gradually increase our knowledge of some of the less definite things which undoubtedly occur.

DR. H. W. ORR, Lincoln, Nebr.: It occurs to me that perhaps we are unduly hesitant about using the common surgical procedure of drainage in this type of case. I had a case during the past year in a girl of twelve who was sent in because of an acute torticollis. Upon examination evidence of the disease was found in the sixth cervical vertebra. Although there was active disease at that point, the roentgen ray evidence was not conclusive as to the amount of destruction. Drainage was done. By the time I got through cleaning out the abscess cavity, I had quite a good sized area of the dura exposed—about the size of my little finger nail. The girl proceeded to get well. Whether or not the infection extended as far as the body of the vertebra I do not know. I went as far as I thought was proper in order to get a cleaning out and drainage of the cavity. I think we should profit in these cases by the experience we have had in other parts of the body and institute early and thorough drainage.

DR. J. T. RUGH, Philadelphia: I would like to ask Dr. Mayer whether it was at all possible to determine the origin of the infection.

DR. LEO MAYER, New York (closing the discussion): The only thing that would give us a clue as to the infection was that the child had had an acute mastoid infection in which the streptococcus viridans was present as one of the bacteria found at the time. That does not prove the etiology.

I think we ought not to hesitate in cases of acute osteomyelitis to drain the vertebrae because they are not inaccessible. I remember when I was a young surgeon I saw the most charming and beautiful girl of sixteen years die before our eyes because our surgeons refused to attack a diseased vertebra. They said it was inaccessible. That is not true. They are very accessible. Dr. Kleinberg operated on a case of dorsal Pott's disease and drained an abscess, and the dorsal situation is more inaccessible than an anterior one.

I am very anxious to have any man who has seen a case of streptococcus viridans infection with definite bone involvement tell me about it, because the literature seems to be extremely sparse.

OSTEOSCLEROSIS WITH DISTRIBUTION SUGGESTING THAT OF THE ULNAR NERVE. AN UNCLASSIFIED BONE CONDITION.

BY PHILIP LEWIN, M.D., F.A.C.S., AND SIDNEY B. MACLEOD, M.D., CHICAGO

INTRODUCTORY REMARK: The writers have presented the original roentgenograms used in illustrating this paper to some of the leading orthopaedic surgeons of the United States and Canada, to several excellent general surgeons, to some international authorities on bone pathology, and several neurologists and roentgenologists. Not one of these men had ever seen or heard of a similar case.

HISTORY: F. B., a white male of 35 years, a pile driver by occupation, was first seen by Dr. S. B. MacLeod on December 4, 1923. He complained of pain and swelling of the ulnar regions of the right forearm, hand, and fourth and fifth fingers. He had caught his hand and arm between a wooden pile and some wooden framework a few days previously, which accounted for his acute pain, but has no bearing upon the subject under consideration.

He stated that he was born near Warsaw, Poland. When six years of age the fourth and fifth fingers of his right hand were found to be swollen. The right ulnar region was soon found thickened and outwardly curved. No cause could be ascribed and he was emphatic in denying injury. He suffered no pain until he was ten years old and for a few years the pain and swelling increased. The pain disappeared, to return at the age of eighteen.

The pain and swelling have not changed since he arrived at the age of twenty-five, except that which followed the injury of December, 1922. At present his pain is more severe during rainy weather. His grip was normal until the age of fifteen, when his hand and fingers were found to be less flexible. The curvature of the ulna and fingers has gradually increased.

His family history is negative. There are no other members with any bone trouble. His mother, father, sister, and two brothers are well. He has a daughter three years old who is physically perfect. He remembers that while a young boy in Poland, his grandfather predicted he would have trouble with the bones of his right forearm and hand until he reached the age of thirty. The significance of this remark in the establishment of an hereditary etiology is problematical.

FIG. 1

Roentgenogram showing distribution of osteosclerosis confined to ulna, ulnar carpal bones and portions of fourth and fiffth metacarpals and their phalanges.

PHYSICAL EXAMINATION revealed an excellent physique with very strong musculature. No pathologic condition was demonstrable except in the right forearm, hand, and fingers. The ulnar region of the forearm was curved outwardly, the skin over the ulnar portion of the dorsum of the hand, viz: the fourth and fifth metacarpals, was red, indurated, and

FIG. 2

Lateral roentgenogram of elbow region showing osteosclerosis of ulna, but humerus and radius unaffected.

sensitive to deep pressure. The fourth and fifth fingers were swollen, outwardly curved and the skin over them was red and shiny. On the ulnar side of the fourth finger there were two knob-like excrescences similar to those seen in gout. On deep palpation of the proximal portion of the ulna, smooth round masses could be easily made out. Examination for deep sensibility, using a number 256 tuning fork, revealed decreased

perception both in degree and duration over the ulnar region of the right forearm, hand, fourth and fifth fingers. These tests included the corresponding areas on the left side and the radial regions on the same side. For example, he felt the vibration stronger, and for from nine to twelve seconds, over the left ulna. Over the right ulna it was weaker and disappeared at the end of five seconds.

The characteristic features of the roentgenograms, which were made by Dr. W. J. Wanninger, were the bone pathology and its unusual distribution.

The bone pathology was characterized by increased bone production, sclerosis, eburnation, almost complete disappearance of the medulla, and obliteration of cortical outlines. New bone was heaped up in round masses. There was an outward curvature of the ulna due to the resistance of the radius, which was not involved in the osteogenetic hyperactivity. The increased periosteal activity producing thickening and the stretching of the periosteum explained in part the pain complained of. There was no atrophy, canalization, or invasion of the soft parts.

In the distribution of the bone pathology lies the chief interest of this report. The involvement immediately suggests the bony structures of the fingers, hand, wrist, and lower forearm, corresponding to the superficial distribution of the ulnar nerve. The bones involved are the entire ulna, cuneiform and pisiform, and the ulnar portion of the unciform, the entire fifth metacarpal, the entire proximal and middle, and part of the distal phalanges of the fifth finger, about one-half of the fourth metacarpal, and the ulnar halves of the phalanges of the fourth finger.

The definition of the process is very sharp. (It can be compared to a condition where it is raining on one side of the street, and not on the other.)

Roentgenograms of the left arm, hand and fingers, and the skull were negative.

Differential Diagnosis: The differential diagnosis rests between the following conditions:

I. Marble bones or Marmorknochen of Albers-Schonberg
II. Paget's Disease or Osteitis Deformans
III. Congenital Osteosclerosis
IV. Silent Osteomyelitis
V. Syphilis
VI. Sclerosing Osteomyelitis of Garré or Infectious Ossifying Periostitis of Bloodgood.

FIG. 3

Roentgenogram showing distribution of osteosclerosis in lower arm, wrist, hand and fingers.

The best means of diagnosis is the removal of a section for microscopic and bacteriologic study.

Marble bones is characterized by a generalized disturbance of the bony structure, evidenced by a marked, irregularly increased density of some portions of the bones, with thinning and rarefaction in other areas. In the long bones the tendency is toward a marked narrowing of the medullary canals in the middle thirds due to thickening of the cortex, with the ends

FIG. 4

Lateral roentgenogram showing limitation of osteosclerosis in phalanges.

of the shaft presenting an expanded appearance, with a thinning of the cortex and a coarsely mottled effect due to increased density in the marrow cavity. The small bones, such as vertebrae, carpals, and tarsals, present a generalized increased density, with absence of bone structure. The epiphyseal lines have slightly irregular margins. There is a general increase of density of the epiphyses with absence of bony structure but of normal size and outline. There may be growth disturbance of the bone length.

The reader is referred to two recent articles by Alexander and Davis.

Paget's Disease or Osteitis Deformans is characterized by deformity

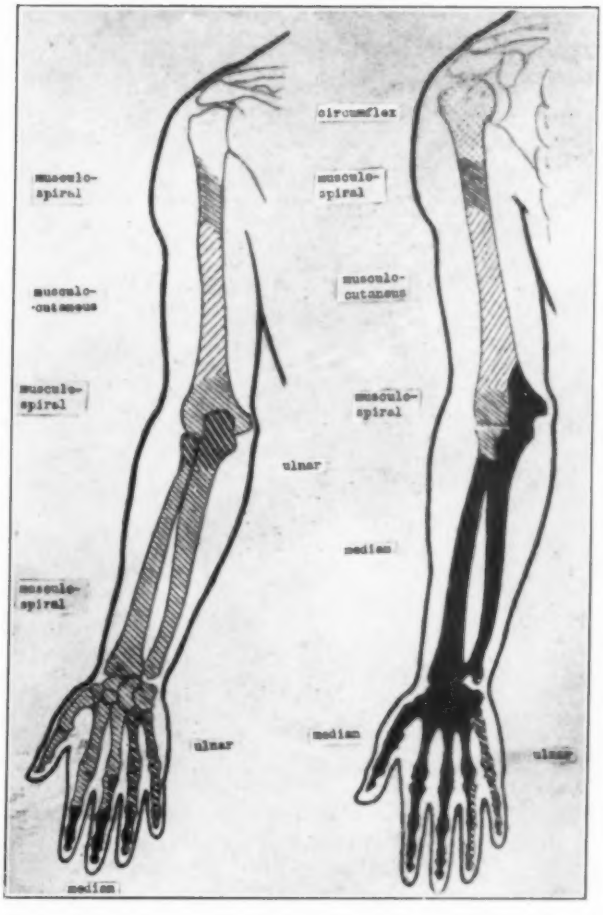

FIG. 5

Nerve supply of the bones and joints of the upper extremity:

Posterior Aspect Anterior Aspect

(Benisty)

of the long bones, usually an outward and forward bowing, especially of the tibia or femur. There is increasing size of the skull, with diminished height of the individual, resulting in a proportionate increase of length of arms producing a "Simian appearance." The abdomen is usually diamond-shaped and the head flexed so that the prognathian chin approximates the sternum. A cervico-dorsal kyphosis usually is present. Roentgenograms reveal a rarefying osteitis with a thick cortex due to subperiosteal and

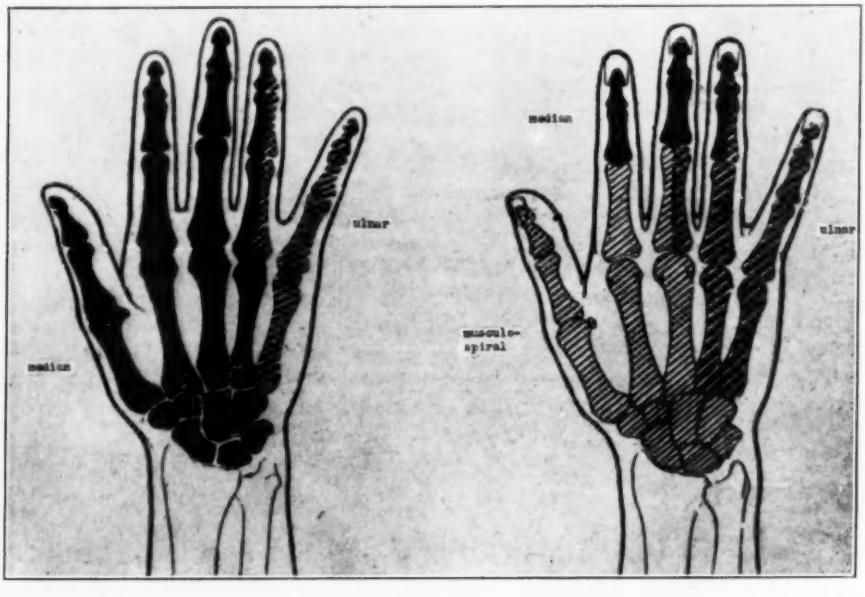

FIG. 6

Nerve supply of the bones and joints of the hand.

Palmar Aspect Dorsal Aspect

(Benisty)

medullary new-bone formation. This thickening occurs along the convex surface. The cranial vault has the appearance of cotton wool or the hair of a pickaninny. Metabolic studies reveal according to Da Costa and others, retention of calcium, phosphorus, and magnesium, with increased elimination of sulphur.

Congenital Osteosclerosis is manifested by a curious density of the vertebral bodies at each pole. There is thickening of the ribs, and in some places the medullary cavity is apparently obliterated. There is thickening

DIFFERENTIAL DIAGNOSIS CHART

	Marble Bones	Paget's Ostitis Deformans	Congenital Osteosclerosis	Silent Osteomyelitis	Sclerosing Osteomyelitis Garre	Syphilis
History	Path.fract. may be first sign	Usually past 40 years. Decrease in height. Increase in size of head. Curvature of long bones.	Congenital Inherited	Usually a complication or sequela of a diffuse osteomyelitis	May be preceded by acute infection	chronic
Pain	+ or —	Vague, rheumatic	Mild. "Growing pains".	May develop painlessly or acute, and continuous; later at night.	Deep aching worse at night and on exertion	Especially at night
Swelling	—	+	—	May be present for weeks before symptoms appear	+	+
Suppuration	—	—	—	Occasionally	—	—
Local Heat	—	—	—	+ or —	+	+ or —
Tenderness	+	+	—	Local	Often deep tenderness.	+
Bones most frequently affected	Generalized	Skull, long bones, tibia femur	Generalized	Long bones	Lower extremity	Long bones and skull
Medulla	Ends expanded. Narrowed in middle 1/3	Decreased	May be obliterated	Affected	Reduced in size	Reduced
Cortex	Thickened in middle 1/3; ends thinned	Thickened	Thickened espec. femur and humerus. Greater in proximal portion	Affected	Thickened	Thickened
Periosteum	Not affected	Thickened on convex side	Not affected.	Affected	Thickened	Increased activity Thickened on convex side.
Density	Epiphyses Increased	Increased	Of vertebral poles increased. Thickening of ribs.	Decreased	Increased	Decreased
Skull findings	Narrowing of basal foramina	Increased in size and thickness. Diploe may be obliterated	Osteosclerosis of base	+ or —	+ or —	Periostitis or gumma.
Pathological exam.	Slight periosteal New bone formation	Confirms roentgen-ray findings.	Confirms roentgen-ray findings	Of osteomyelitis	Confirms roentgen-ray findings	Of syphilis
Treatment	Heliotherapy Diet Hygiene Medicinal	Unknown	Unknown	Operation	Operation	Hg.KI. Arsenic
Prognosis	Poor	Poor	Poor	Good	Usually recurrents	Poor

FIG. 7

Differential Diagnosis Chart of Some Bone Conditions.

of the cortex of all the long bones, more marked in the femora and humeri, and the cortical thickening seems to be greater in the proximal portion of these bones than in the distal portion. The skull is thicker than normal. In the femoral neck there seems to be a breaking down of the bone just below the epiphysis so that this structure is slipped inward and downward.

Silent Osteomyelitis should be excluded easily by its location, distribution, and roentgenographic findings. Phemister's recent article on this subject is excellent.

Syphilitic Osteitis is manifested by a preponderance of bone production and increased periosteal activity, but does not have a peculiar distribution as seen in the case here reported.

Garré's Sclerosing Osteomyelitis or Infectious Ossifying Periostitis of Bloodgood: Localized proliferative chronic non-suppurative sclerosing osteitis is revealed in the roentgenogram by a spindle-shaped thickening of the bone. The medullary cavity is reduced in size, and the bone is increased in density. The pain is a deep aching, worse at night and on exertion. The lower extremity is more often involved. There is local swelling, heat, and often tenderness on deep pressure. Recent articles by Henderson, Fosdick Jones, and Bloodgood are referred to.

SUMMARY

We have presented a brief history, physical examination, and roentgenograms of a condition of unusual bone pathology characterized by a peculiar distribution confined to the bony structures of the lower forearm, wrist, hand, and fingers, corresponding with the superficial ulnar nerve distribution plus the entire ulna. The changes in the bones are characterized by increased production of bone, sclerosis, eburnation, almost complete disappearance of medulla, with obliteration of cortical outlines, slight periosteal thickening, lack of atrophy, or canalization, and no invasion of the soft tissues. The ulna is outwardly curved and there is decreased deep sensibility to tuning-fork tests applied to the bones involved. The etiology may lie in a congenital anomaly or a neurologic or vascular disturbance.

Dr. C. Judson Herrick says that if there is a nervous factor in this case it does not correspond with peripheral distribution nor spinal cord segmentation, but with spinal root or spinal ganglion segmentation, in which case it might be of spinal ganglion origin or of sympathetic efferent connection, by way of the eighth cervical or first thoracic roots.

REMARKS: The writers are unfortunately unable to furnish any other data in regard to history, serological tests, blood chemistry, microscopical

or bacteriological examinations, because the patient does not know the first and will not permit the others. They would appreciate any assistance in classifying this condition.

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Paget's Osteitis Deformans

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DISCUSSION

DR. H. W. MEYERDING, Rochester, Minnesota: It was my privilege to see the original roentgenograms which Dr. Lewin presented to the Clinical Orthopaedic Society in Cleveland, and later to re-examine them at Rochester. We were very much interested in this unusual distribution and I considered it a fibro-cystic disease. It is not unusual to find this condition involving one extremity, and if you will recall, there are found both the singular and multiple types of osteitis fibrosa cystica. I recall one patient upon whom we operated for non-union of the femur, and in whom we found involvement to include the tibia and fibula. The consistency of this bone was just about that of brick cheese, the bone being soft and easily cut with a heavy knife. Later the roentgenograms showed the bone to be united and a sclerosis occurring.

Dr. Lewin's patient may have had osteitis fibrosa cystica as described by von Recklinghausen at the age of five, and the present condition may have resulted from sclerosis of the involved bone. It would therefore be interesting to know whether there was any disease of the bone at an early age.

DR. S. FOSDICK JONES, Denver: I have been very much interested in Dr. Lewin's case. There is very little to add to his report. It is an unusual condition. I think

there is one great thing that we must all remember in these bone conditions and that is, the pathological examination which must be undertaken before a definite diagnosis can be established. In cases of sclerosing osteomyelitis the most difficult condition from which to differentiate is osteogenetic sarcoma in which there is a typical fusiform enlargement affecting the long bones. These cases of sclerosing osteomyelitis are extremely rare, but must be, as I say, differentiated from bone sarcomata and a pathological report made before the case can be definitely classified.

I should say that Dr. Meyerding's suggestion relative to the case of Dr. Lewin was the most probable diagnosis, there being an osteitis fibrosa cystica that has gone on to a partial rarefication of the bone. Against it is the obliteration of the medullary canal, which is seen in sclerosing osteomyelitis and which is rather characteristic of that disease.

Dr. Ralph Ghormley, Boston: About three years ago we had in the clinic at Johns Hopkins a case which was diagnosed as congenital osteosclerosis. It differed from this case, but there were some points of similarity. The patient was a boy of eight years, with the history of a little limp. The roentgenogram showed a little epiphyseal separation, a very thickened cortex, and a very dense ossification of the entire bone. We took radiograms of the entire skeleton and found that the condition extended over all the bones of the trunk, the cortex of the long bones, and the skull. On looking up the literature on the subject we found several cases of reported autopsies showing that all the patients had died of some form of blood disease, some form of leukemia. This patient had no trouble in that way, but was perfectly normal. All the other laboratory tests were negative. The most interesting thing in this case was that the father's bones showed the same thing. Later on a roentgenogram of a paternal uncle showed the same thing. It was a congenital osteosclerosis. What the etiology was I do not know. The appearance of the bones resembled the appearance of the bones in Dr. Lewin's case, but the distribution was entirely different.

Dr. E. G. Mumford, Indianapolis, Ind.: Your President very kindly consented to allow me as a guest to present some slides on some cases of bone lesions associated with nerve lesions. I thought these would be of interest because they are unquestionably bone conditions.

One patient was a man of fifty who had infantile paralysis as a child and later, at the age of twenty, developed a lesion beneath the fifth metatarsal which gave him some trouble, in that every six months or a year he had a little serous discharge and the foot was a little bit painful for twenty-four to forty-eight hours. He had an infection later which led to amputation of the leg. When I cut through the tibia it was perfectly normal, but when I came to the fibula it was represented by a very hard, chalky bone without any medullary canal. I have not the slides on that particular case. I have the roentgenograms of three other cases which show very definite changes for which I have never had a satisfactory explanation. They were all associated with a paralysis of the peroneal muscle and show a definite change in the fifth metatarsal bone, which is not typical of the ordinary osteomyelitis, but which represents a trophic change in the bone.

Dr. F. J. Gaenslen, Milwaukee, Wis.: I would like to ask Dr. Lewin whether there is any evidence of circulatory disturbance in the arm. It seems to me that both circulatory and peripheral nerve conditions must be considered in arriving at a conclusion as to etiologic factors involved.

DR. PHILIP LEWIN, Chicago (closing the discussion): Dr. Meyerding's suggestion is very important. We see radiograms of various bone conditions and we see radiograms of certain definite entities in various stages and think they are different conditions. If this boy had a fibro-cystic disease in the long bones years ago, I cannot see how he had it in his three ulnar carpals and in the carpal phalanges of four or five fingers, but if he had it at the age of six, then something else happened to him and he developed the condition which shows in the radiogram. I do not see how we could tell except by section at various stages during his life.

I do not think we can call this fragile bone because one of the reasons he went to the doctor was because this right arm was caught in a wooden framework. The doctor had a roentgenogram made, thinking there was a fracture because the injury was very severe. If he had fragile bones the injury should have smashed them. It might be von Recklinghausen's disease.

Dr. Fosdick Jones struck a very important note when he said the pathologic examination and the histologic examination were most important in determining the condition. We made a blood count and a spinal fluid examination in this case. It took sixteen months to get the patient to allow us to have a second X-ray picture made. He did not want this investigated. He was satisfied and if it were not for the fact that he had injured the arm he would not have come to the doctor.

I do not believe an osteogenetic sarcoma would have this picture. I am familiar with Henderson's work, also with Bloodgood's work on infectious osteitis, and Dr. Ghormley's work on congenital osteosclerosis. These are all excellent works and I have tried to make this condition conform with some of them, but I have been unable to do so. Much investigation is necessary along the line of distribution of the peripheral nerves to the bones and joints. I could not find anything on the subject except in Benestree's work and in some work by Duchenne. We ought to be able to examine these nerve lesions ourselves without sending them to a neurologist.

Dr. Gaenslen made an excellent point when he said this might be a circulatory disturbance producing a calcification. Remember, however, that calcification is not ossification and that the calcification as it occurs in the ovary due to vascular disturbance has nothing to do with the nerves whatsoever. When I showed this case to Dr. C. Judson Herrick, the first thing he said was that it corresponded to the nerve distribution. The peripheral nerve distribution is not the same as the superficial nerve distribution.

HEREDITARY DEFORMING CHONDRODYSPLASIA. REPORT OF THREE CASES.*

BY HORACE E. CAMPBELL, M.D., CLEVELAND, OHIO

Hereditary deforming chondrodysplasia is a disease characterized by the multiple cartilaginous exostoses which occur near the ends of the diaphyses of the long bones. It has been variously named,—multiple cartilaginous exostoses, multiple cancellous exostoses, ossified diathesis, rachitiform enchondrosis, multiple congenital osteochondromata, diaphysial aclasis, etc.,—but the term which best describes the disease is the one given by Ehrenfried in 1915, hereditary deforming chondrodysplasia (Locke).[5] The lesions characterizing the disease were repeatedly described in the early literature, but only recently has it been clearly recognized as a definite entity. The first case reported in this country was by Gibney[4] in 1875. In 1915 Ehrenfried[2] collected about six hundred cases reported in three hundred articles, and in 1917 the same author[3] assembled ninety-nine cases from the American literature.

Little is known concerning the etiology, but the most probable explanation is that there is a "disturbance in development of the intermediate cartilage due to an original defective anlage" (von Bergman).[1] It is definitely associated with the period of bone development and probably in all cases begins in early infancy, although the exostoses may not be noticed until the fourth to the tenth year, or even as late as the thirtieth year. It predominates in the male sex as much as three or five to one. It is clearly hereditary, and the familial occurrence is demonstrable in the majority of cases (Percy).[6]

The essential lesion is a striking overgrowth of bone which appears as an extremely irregular, ragged, often cauliflower-like proliferation. It may encroach on the epiphysis and even interfere with free movement of the joint. Since the disorder is plainly a disturbance in the proliferation and ossification of the intermediate cartilage during the period of growth, it follows that the lesion is most typical and in greater abundance at those sites where bone growth is most rapid, i.e., at the knee, ankle, hip, and wrist. On section, the tumors are seen to be covered throughout with a thick

*From the Surgical Clinic of the Lakeside Hospital, Cleveland, Ohio.

glistening cartilage. Beneath the enveloping cartilage is a layer of hyaline cartilage and osseous tissue of variable thickness. The microscopic appearances of the cartilage are those of a greatly disordered and excessive growth. Throughout the zone of proliferation are irregular masses of cartilage cells without orderly arrangement and often with incomplete calcification.

There is sometimes a degree of skeletal growth retardation, with partial dwarfism, and deformity of joints due to shortening of one of the two bones of the leg or forearm. There are no primary symptoms or constitutional manifestations. Complications are rare, but malignant disease, fracture, erosion of blood vessels, and nerve pressure may occur in relation to the lesions. Drug therapy has thus far proved ineffectual, and treatment has been aimed at relief of pressure symptoms, deformities, and the removal of unsightly growths.

In the records of the Lakeside Hospital, Cleveland, there have been recorded only three cases in the last ten years. These are reported because of the unusually interesting roentgenographic findings.

CASE NO. 1. J. R., male, age 21, single, admitted March 23, 1914.

Complaint: Lumps growing from bones.

Present Illness: Lumps first noticed by patient's mother when he was two or three years old. There were first two small lumps on right wrist, which grew gradually larger. Later other similar lumps appeared and grew slowly. New ones were continually appearing until three years ago, when the last one appeared on the right thumb. The masses were variable in rate of growth but seemed to grow constantly larger until three years ago, soon after the appearance of the last one, when all ceased growing; they have not receded. They are painful only when struck. The patient has general muscular weakness; otherwise health is good.

Past History: Has had whooping cough, mumps, and orchitis. Has tendency to colds, with a chronic cough and yellowish expectoration from posterior nares. Has had attacks of headache with dizziness, nausea, and vomiting about once a week, lasting two or three days, ever since he can remember. These attacks are sometimes accompanied by sore throat. Is somewhat worried about his condition, otherwise sleeps and eats well. He is maintaining his usual weight of 130 pounds.

Family History: Father died of cancer of stomach, mother of cancer of throat. A half-brother and half-sister are living and well. There is no similar affection in any of the family.

Examination: Skin, mucous membranes, and subcutaneous tissues normal. Tonsils enlarged, pharynx injected. Teeth poor. Posterior cervical glands "shotty." Thyroid slightly enlarged. Chest is asymmetrical due to bony exostoses of scapulae and ribs. Respiration is largely abdominal, as patient experiences difficulty in expanding chest. Practically no rotation of ribs on inspiration. Lungs are normal. Heart is slightly enlarged, with split first sound heard all over the precordium with maximum intensity in fifth space, parasternal line. Aortic second slightly accentuated. No murmurs. Abdomen, reflexes and genitalia are normal.

The bones present hard bony masses which are firmly attached near the epiphyses. The skin is freely movable over them; some are rough and others smooth, and the size is quite variable. They are widely distributed over the body.

Skull: Normal.

FIG. 1

Case 1. Left humerus. Note unusual width of disturbed zone.

Spine: Spines of the fifth cervical, first, second, eighth dorsal, and second lumbar are slightly enlarged. No scoliosis, or kyphosis, but there is a slight apparent lordosis due to the relative enlargement of the second and eighth dorsal spines.

Clavicles: Both are abnormally thick, the acromial ends are thickened, broad, and heavy. On the anterior superior aspect of the sternal extremity of each bone is a small exostosis, and the shafts are broad and thick.

FIG. 2

Case 1. Right forearm, the site of the original lesion, showing the marked shortening and the deformity of the head of the radius. There is evidently a synostosis of the lower ends of the bones.

Scapulae: Left shows more deformity than right; along the vertebral border and arising from the infra- and supra-spinous fossae is a very large mass which pushes the body of the scapula out, giving the appearance of a wing. In the infra-spinous fossa is a discrete nodule. There is a marked exostosis on the spine of each scapula, larger on the left.

Humeri: Large masses on the left in region of greater tuberosity, medial aspect of

FIG. 3

Case 1. Showing the numerous lesions and the painful tumor on the terminal phalanx of the thumb.

surgical neck, and on outer aspect of mid-shaft (Fig. 1). One mass on the right on outer aspect of shaft, and masses on the internal and external epicondyles of both humeri.

Radii and Ulnae: The right ulna is shortened by four cm. and there are masses on the dorsal surface of both bones just below the elbow, and at the distal extremities of both bones (Fig. 2). There are masses at the distal ends of the left radius and ulna.

Metacarpals: Small masses on shafts on right and left.

Phalanges: Mass on medial side of distal phalanx of right thumb. The third finger of the right hand shows a pseudoarthrosis in first phalanx (Fig. 3).

FIG. 4
Case 1. Marked involvement below the right knee.

Ribs: Small exostoses on all the ribs, particularly at junction of bony and cartilaginous portions.

Pelvis: Marked involvement, especially noticeable in the roentgenogram.

Femora: There are no masses on the shafts, but many at the distal epiphysis, and the largest tumor that is presented is at the distal end of the right femur.

Tibiae and fibulae: Large masses just below knee on right (Fig. 4).

Tarsi and phalanges: Normal.

Laboratory: Blood Wassermann: Negative. Urine: Negative for albumen, sugar, casts, pus, and Bence-Jones protein bodies.

R. B. C.	5,460,000	
W. B. C.	13,000	
Differential:	Polys	71
	Small monos	19
	Large monos	6
	Transitionals	3
	Eosinophiles	1
	Basophiles	0
	Pathological	0

About six months after the first admission, a painful mass was removed from the distal phalanx of the right thumb (Fig. 3), but no microscopic studies were made.

Comment: The mass should not be considered as inherently painful, but, due to its location on the tip of the right thumb, was being constantly subjected to pressure and trauma. The widespread distribution in this case is noteworthy, and the largest and most frequent masses are at those points of most rapid bone growth, the knee, wrist, and elbow.

Case No. 2. L. Y., age 8, admitted July 7, 1916.

Complaint: Lumps on legs and feet.

Present Illness: The first lump was noticed when the patient was one year old, and was found on the upper arm. The next one appeared two years later on the left foot. Many have appeared since then; they are painful upon first appearance, but the pain ceases as they become larger. They do not cause any disability, but the child does not play as the other children do. A tumor was removed from the left ankle at another hospital about two years ago.

Past History: Essentially unimportant.

Family History: The mother, father, the one brother, and the one sister are living and well. The mother had four lumps like those of the patient, but they went away at the age of fourteen. No other cases among the ancestors or relatives are known.

Examination: A well nourished, bright-looking, fair-skinned, somewhat under-sized blond boy whose general examination is negative. There are multiple bony tumors on the long bones.

Skull: Normal. Spine: Normal. Clavicles: Normal. Humeri: Normal.

Radii and Ulnae: On the right there are several exostoses at the distal end of the radius and ulna, and on the left, one large one at the distal end of the radius laterally. Metacarpals: Small masses on three of the left metacarpals. Phalanges: Normal.

Ribs: Small tumors at the costo-chondral junctures of the right fourth and fifth ribs.

Pelvis: Normal. Femora: Large masses on both sides of the distal end of the right femur, none on the left. Tibiae: A large mass on the lateral surface of the proximal end and a small mass on the medial surface of the distal end of the left tibia, none on the right. Fibulae: Normal. Tarsi: Small mass on the lateral aspect of the left talus.

Laboratory: Urine: Negative for albumen, sugar, casts, blood, and pus.

Biopsy: July 10, 1916. The small mass on the medial surface of the lower end of the left tibia was removed and found to consist of a bony shell with dense cancellous vascular interior. At places the shell was cartilaginous, there was no distinct base, and the interior of the mass was continuous with the marrow cavity of the tibia. Microscopic section showed the mass to consist largely of dense firm cartilage, with irregularly deposited cancellous bone. In some areas it seemed as though the shell were covered with periosteum. Histologic study showed considerable new bone formation, a marked amount of cartilage with irregular arrangement of the cells and much fibrous and hyaline cartilage. There was bone deposit in some of the cartilaginous tissue.

Comment: The microscopic study assures us of the correct classification of the case.

Case No. 3. E. A., female, age 12, admitted Aug. 20, 1924.

Complaint: Swellings on bones.

Present Illness: At the age of two and a half years the patient had pneumonia and it was following this illness that the mother noted a swelling on the second phalanx of the third digit of the right hand. This was followed by several others which seemed to appear in groups and were at first painful. There has been no pain since the age of three years, and no new masses in the last three years, i. e., since the age of nine. There has been little or no interference with the function of the bones or joints.

Past History: Normal, full term babe, with normal delivery. Following the pneumonia noted above there was a non-productive cough for four years. There have been frequent sore throats which have become more severe the last three years, and she entered the hospital primarily for tonsillectomy. One year ago had scarlet fever, and following this an abscess on the right side of the neck, which was incised. Patient states that she gets out of breath easily.

Family History: The mother and father are living and well. There are three brothers and three sisters, all living and well. No history of similar affection in any of ancestors or relatives.

Examination: A well nourished girl of twelve years. Skin, mucosae and subcutaneous tissues normal. Head and neck normal. Tonsils hypertrophied. Thorax and lungs negative. The heart presents rather marked sinus arrhythmia, is otherwise negative. Abdomen is negative. On various bones throughout the body there are round, hard, bony tumors of varying size, immovably attached to the bones, and not attached to the skin. The skin overlying is normal, the masses are not painful or tender. They tend to occur at the epiphyseal areas, but do not interfere with articulation except in one area at the lower end of the right forearm, interfering with pronation and supination. Their distribution is as follows: Skull: None. Spine: None. Ribs: None. Clavicles: One on the superior surface of the outer third, left. Scapulae: On the superior vertebral angles bi-laterally. Humeri: Right, proximal end on both the medial and lateral aspects (Fig. 5). Radii and Ulnae: There is a large mass at the lower end of the right radius and ulna forming a synostosis between the two bones (Fig. 6). There is apparently a mass on the lateral surface of the proximal end of the same ulna, but the roentgenogram shows this to be the dislocated head of the radius (Fig. 6). None palpable

FIG. 5
Case 3. Right humerus.

FIG. 6

Case 3. The mass has originated from the ulna but has apparently united with the radius. Note dislocation of head of radius due probably to interference with growth of ulna. This head of the radius was mistaken for an exostosis on the lateral aspect of the olecranon.

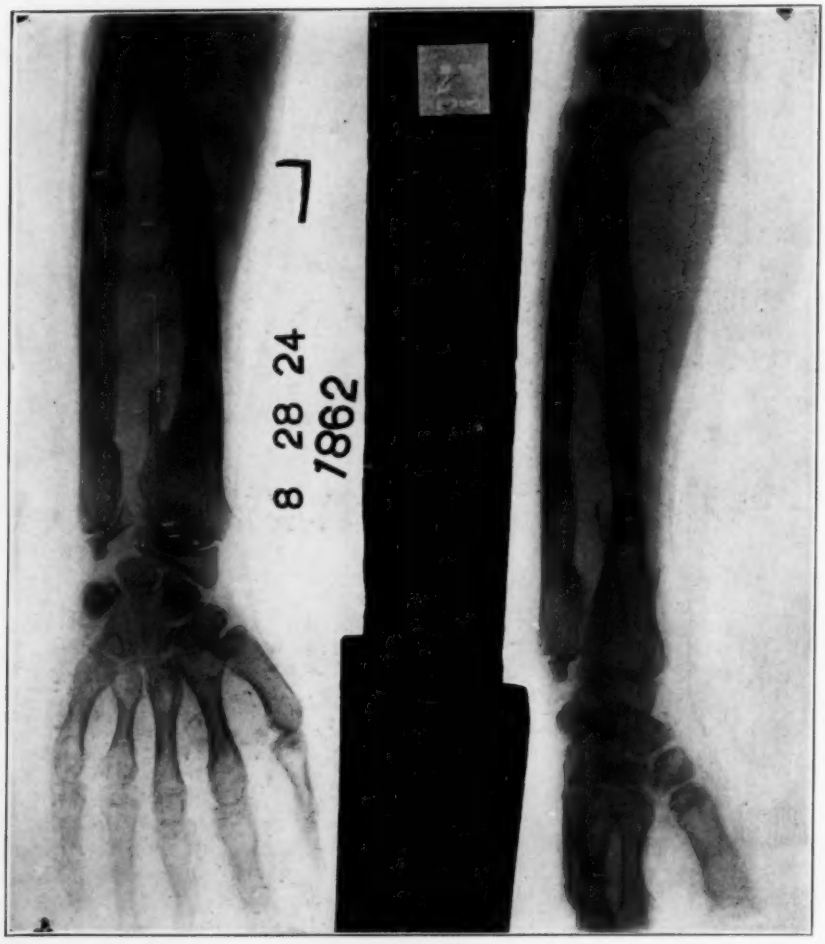

FIG. 7

Case 3. Showing a small amount of disturbance of growth at the left wrist which was not perceptible without the X-Ray.

on the left (Fig. 7). Carpi: Negative. Phalanges: There are small masses on bones of the fingers, the largest being the original one on the second phalanx of the right middle finger. There are none on the thumbs (Fig. 8). Femora: There are exostoses on both femora just above the condyles both medial and lateral. Tibiae: There are masses on the

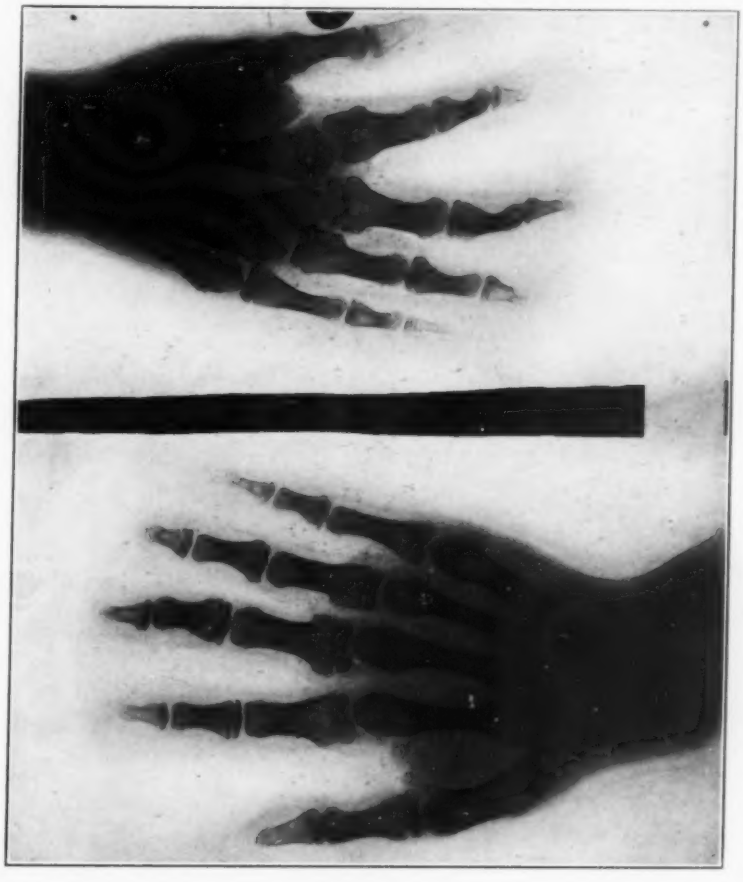

FIG. 8

Case 3. Showing involvement of right hand.

medial surfaces of the tibiae at both the distal and proximal ends (Fig. 9). Fibulae: On both heads, and just above the lateral malleolus of the left (Fig. 10). Tarsi and Phalanges: Negative.

Laboratory: Urine: Negative in routine examination and for Bence-Jones protein. Wassermann: Negative. Hemoglobin: 85 per cent. W. B. C. 13,000.

FIG. 9
Case 3. Involvement of the heads of tibia and fibula, left.

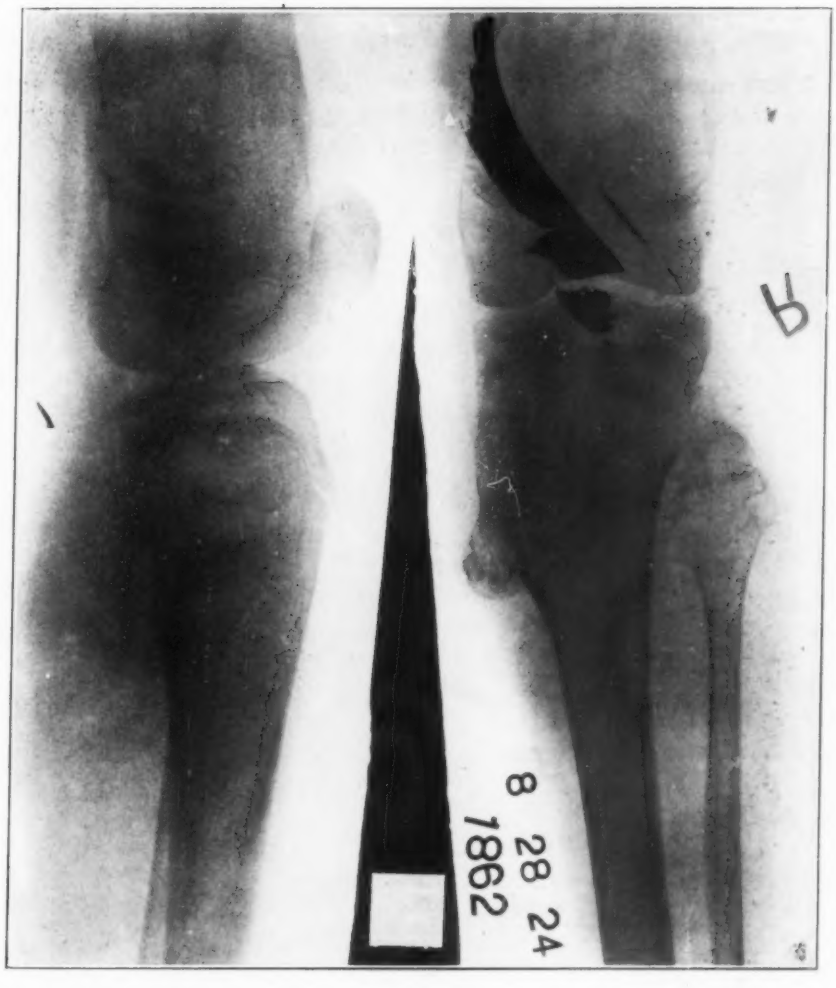

FIG. 10
Involvement of the heads of tibia and fibula, right.

Comment: Biopsy was not permitted since, in spite of the considerable deformity and the interference with full pronation and supination, operative procedures were not indicated.

SUMMARY

These cases of Hereditary Deforming Chondrodysplasia are presented with roentgenographic studies. The latter are of particular interest and depict well the widespread involvement of the disease and the many forms which this disease may assume.

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MALFORMATION OF THE LOWER SPINE BASED ON A ROENTGENOGRAPHIC STUDY OF CHILDREN AND ADULTS

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Roentgenograms of the lumbo-sacral region in cases of painful back show many anatomic variations. Some of these would seem to be the direct cause of pain. There is still, however, considerable confusion about the significance of these changes. Knowledge of their frequency in the so-called normal back would be of value in estimating their importance in cases of back-ache.

In order to throw some light, if possible, on this subject, I have studied three series of roentgenograms of the lumbo-sacral region. The first was of adults, whose backs were apparently normal, and who had never had back-ache. These varied in sex, in age from sixteen to sixty-eight, and in occupation from student to laborer. The second comprised children, who were supposed to have normal spines. These were patients in the St. Louis Children's Hospital for various medical and surgical conditions, but whose spines were supposedly normal. The third consisted of scoliosis cases taken at random from the files of the Roentgen Ray department of the Washington University Medical School. The object of examining this series was to see the relation, if any, between lumbo-sacral variations and scoliosis.

The anatomic variations sought were: large transverse spinous processes of the fifth lumbar vertebra which might impinge on the ilium; sacralized transverse processes of the fifth lumbar vertebra; bifurcation of the fifth lumbar or the first sacral, and other structural anomalies. Slipping of the lumbo-sacral articulations and developmental abnormalities, though not anatomic variations, were also noted.

The first series, normal adult spines, comprised twenty-nine cases. Sixteen, or 55 per cent., showed varying degrees of abnormality, some showing several varieties. Four, 14 per cent., showed variations in the transverse process of the fifth lumbar which might possibly have caused back-ache. There were four cases, or 14 per cent., of sacralized transverse

process, three double and one on the left side, as compared with 8.5 per cent. in cases of painful back, reported in a paper on "Backache and Anatomical Variations of the Lumbo-Sacral Region,"[1] read before the American Orthopaedic Association in 1920. There was one bifid first sacral, three per cent., as compared with six per cent. in the series of painful backs. In

FIG. 1

Normal Adult Spine. Male, 44. Large transverse processes.

four, 14 per cent., there seemed to be a slipping of the lumbo-sacral articulation. Six showed a lateral displacement of the spine on the sacrum, four to the left, and two to the right. In two there was scoliosis with some rotation, and in one rotation without scoliosis.

The second series consisted of forty-five plates of normal spines in children. Only one, 2 per cent., long transverse process, was found. There were only two, or 4 per cent., sacralized transverse processes. This is an interesting fact when compared with 8.5 per cent. in painful backs

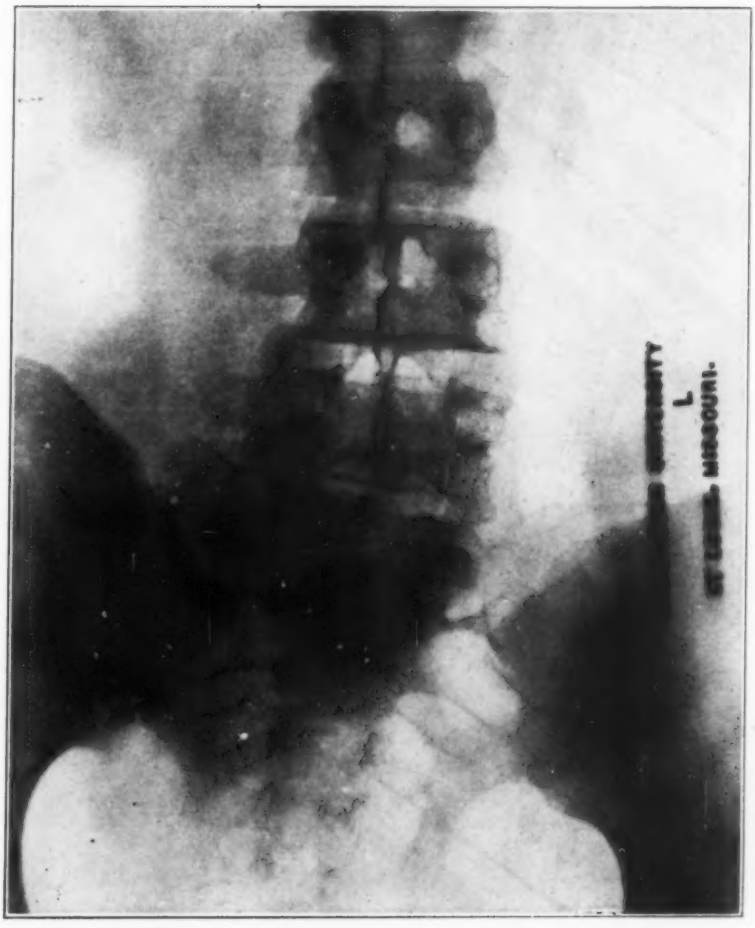

FIG. 2

Normal Adult Spine. Female, 35. Large transverse process. Bifurcation of first sacral spinous process. General irregularity of lumbo-sacral articulation.

and 14 per cent. in normal adults. There was one on the left and one double. In three cases, 7 per cent., bifurcation of the fifth lumbar and first sacral was present. Bifurcation of the first sacral spinous process

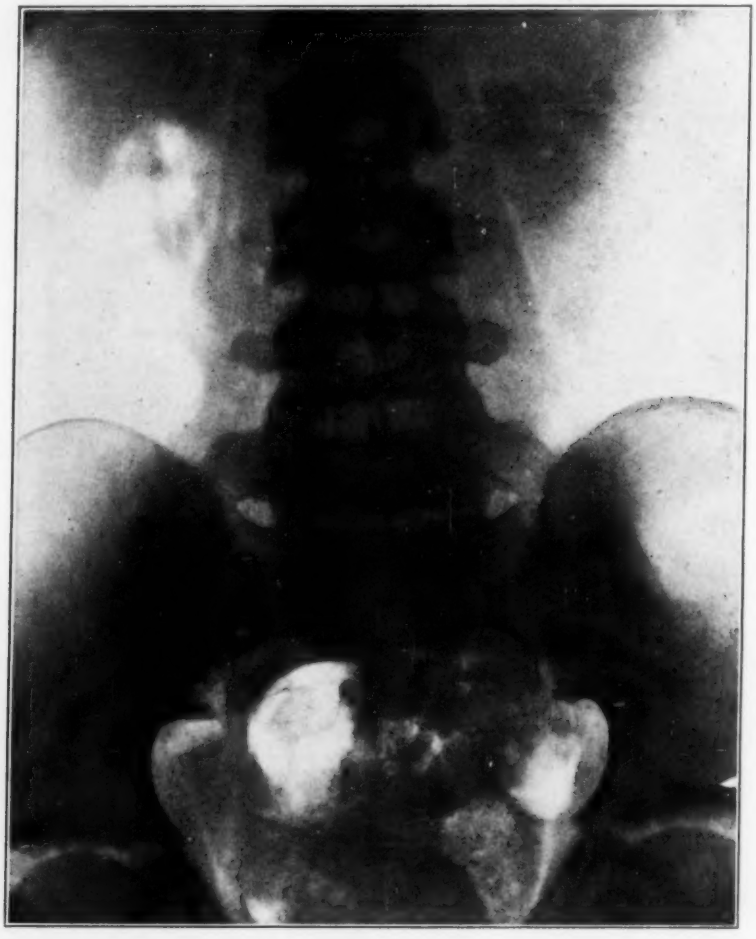

FIG. 3

Normal Child's Spine. Large transverse process, double, almost sacralized.

was most striking. Thirteen plates showed this condition. This, however, does not represent its true frequency. The ages of these children ranged from four to fourteen years, so that in most cases the apparent bifurcation

was probably due to incomplete ossification. Two cases, however, seemed to show a definite structural defect, giving 4 per cent. as compared with three per cent. in normal adults. There was some slipping of the lumbo-

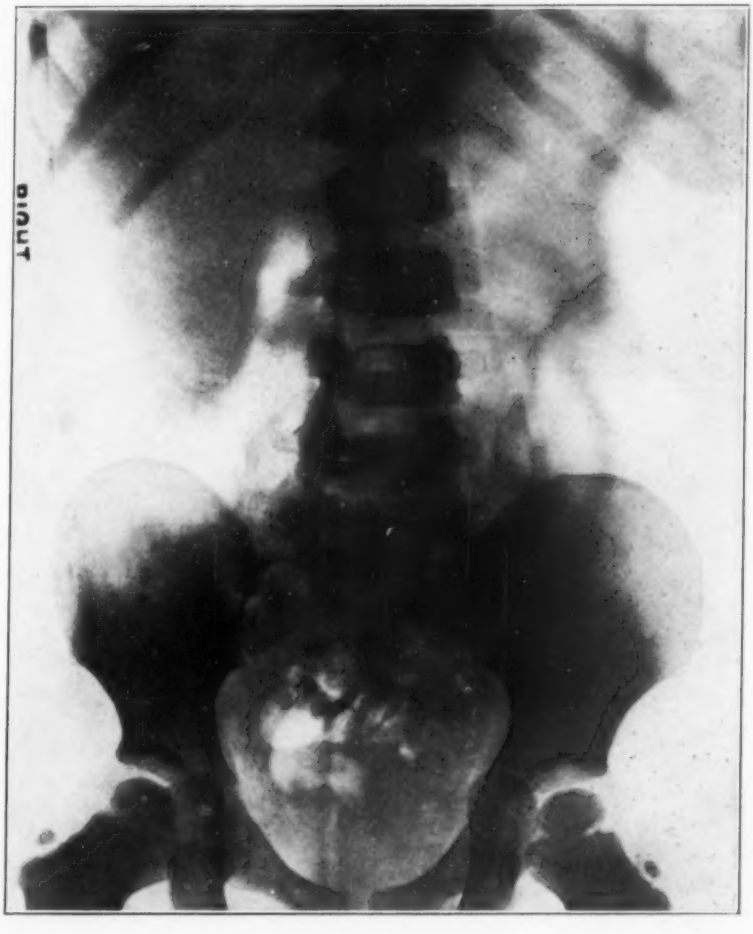

FIG. 4

Normal Child's Spine. Large transverse process. Irregular lumbo-sacral region.

sacral articulation in two cases, or 4 per cent. Scoliosis was present in one and a general irregularity and asymmetry in four, 11 per cent. On the whole this series seemed to be rather free from abnormalities.

In the third series, scoliosis, the changes were much more marked. Thirty-seven plates were examined: of these, twenty-five, 68 per cent., showed abnormalities in the lumbo-sacral region. In most of these the

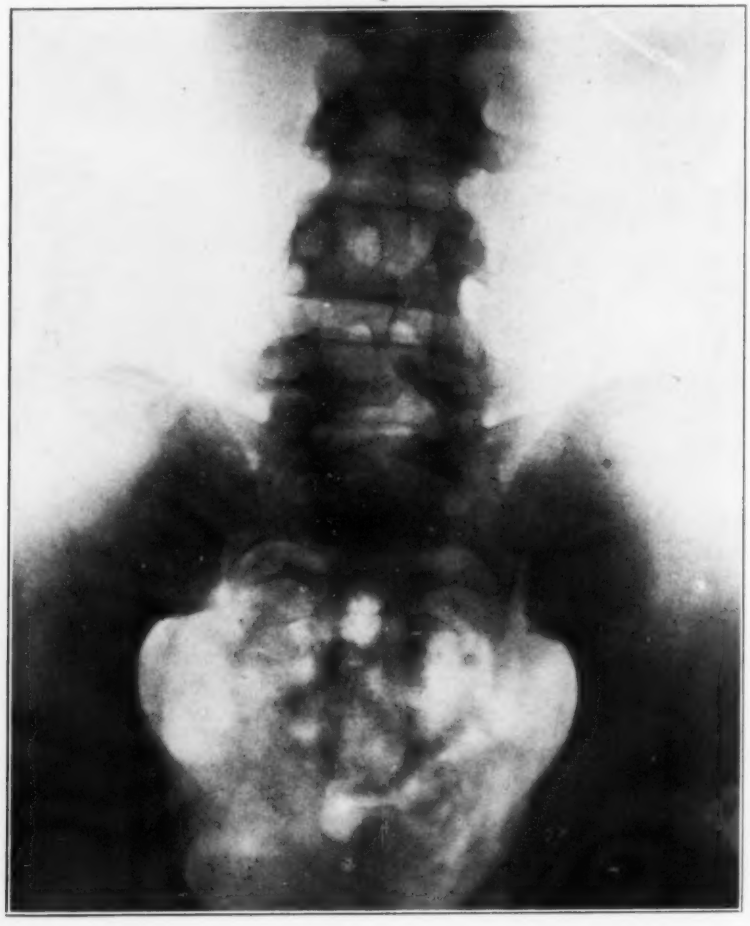

FIG. 5

Normal Child's Spine. Bifid first sacral and fifth lumbar spinous process.

variation was marked. In practically all, the sacrum seemed to be tilted, and the articular line of the sacro-iliac joint seemed wider than in the normal, and in two cases it was definitely displaced. In all cases with

rotation there was slipping of the lumbo-sacral articulation on the side of the curve, and all curves were left lumbar. It is impossible to say whether the slipping of the articulation was the cause of the scoliosis or whether

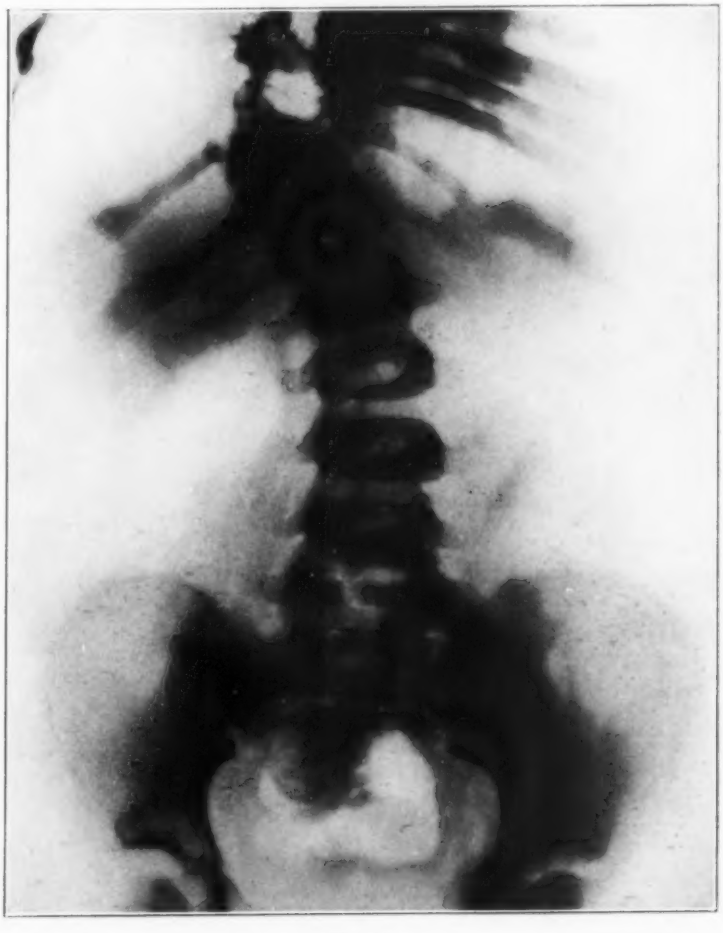

FIG. 6

Scoliosis. Large spinous process on one side which does not seem to influence the scoliosis.

it was due to the rotation. I think, however, that in most cases it accompanied rotation. In ten cases, 27 per cent., there was a sacralized transverse process, on the right in five, on the left in one, and double in four.

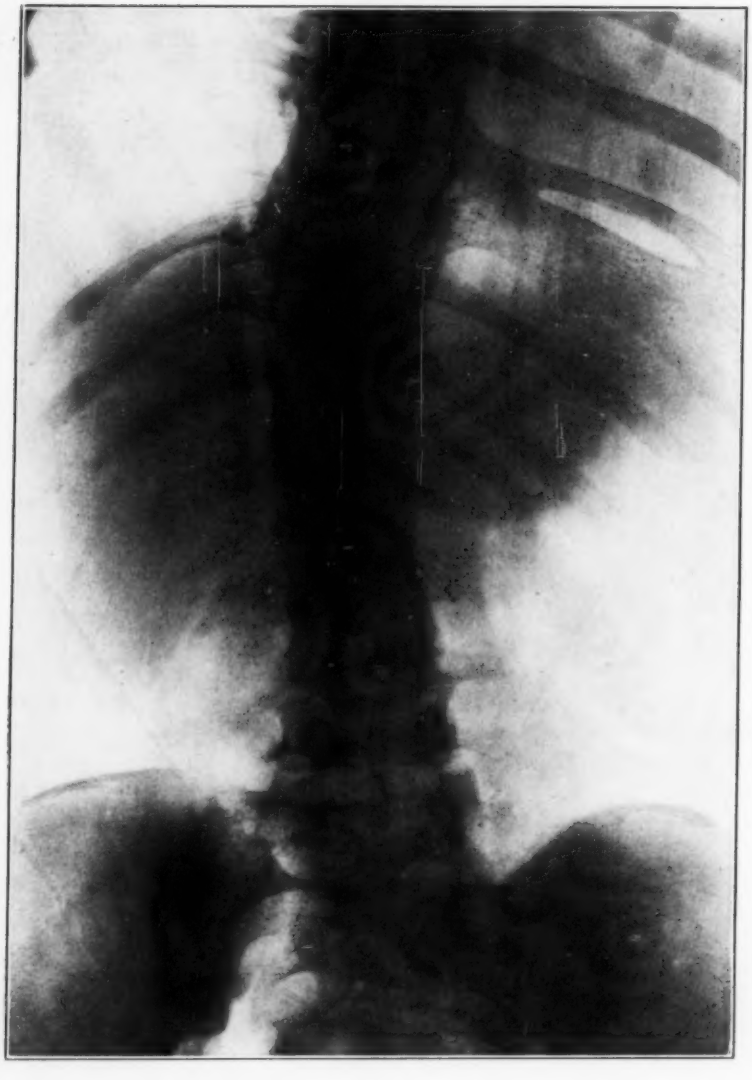

FIG. 7
Scoliosis. Numerous congenital defects.

This is a marked increase over the other groups studied and would tend to indicate that the sacralized transverse process plays an important rôle in the etiology of scoliosis. The first sacral process was bifid in five, 14 per cent. In one case there was fusion of the ribs, spina bifida, and other anomalies, and in another there were only eight ribs on one side.

TABLE

	Painful Backs	*Normal Adults*	*Normal Children*	*Scoliosis*
Large T. V. P.	25%	14%	2%	
Sacralized T. V. P.	8.5%	14%	4%	27%
Bifid 5th, L. and 1st Sac.	0	0	7%	0
Bifid 1st, Sac.	6%	3%	4%	14%
Slipping Artic.		14%	4%	68%
Other Changes		31%	11%	Many

It would seem from an examination of these plates that we have the same variations in the apparently normal spine as in the painful back. The large transverse process of the fifth lumbar is much more common in painful backs than in the normal adult spine, 25 per cent. to 14 per cent., while in children there were only 2 per cent. It is possible that the long transverse process might cause back-ache, not so much by actual impingement as by more readily allowing ligamentous strain.[2] It is also possible that the small percentage, 2 per cent., in children is due to the fact that the process has not as yet fully developed and consequently does not show in the roentgenogram. The discrepancy in the proportion of sacralized transverse processes between painful backs, 8.5 per cent., and normal adult spines, 14 per cent., is hard to explain. It would, however, bear out Moore's suggestion in a recent paper,[3] that, "Anatomically and architecturally the sacralized formation appears stronger and more able to resist strain than the usual arrangement." This would seem especially true in the double type, and in this series there were three double and one single. The small number in children would suggest the fact that ossification had not progressed far enough to make the condition readily distinguished by the roentgen ray. It is also possible that in a larger series the percentage would be closer to that in the normal adult spine. In twenty-eight roentgenograms of cadavers studied a few years ago there was not one sacralized transverse process.[2] My statistics do not agree with those of Moore, who found true sacralization in 3.5 per cent. of his cases. I have not confined myself, however, to true sacralization, in which there is bony union between the transverse process of the fifth lumbar and the sacrum, but have also included those cases in which the transverse process

is very large and to all intents and purposes is sacralized, though there may be a line of demarcation between it and the sacrum. This type is probably more frequently the cause of back-ache than the true sacralized process.

Bifurcation of the first sacral vertebra is not as common as the other anatomic changes. It is practically the same in normal adults and normal children, but is slightly larger in painful backs and very much larger in scoliosis. It would seem that it might possibly play a part in the production of painful back.

In scoliosis the anatomic and developmental variations are all more frequent than in the other series. This is to be expected, especially in the case of the large unilateral transverse process which undoubtedly is an important factor in causing scoliosis.

CONCLUSION

It would seem from this study that variations in the lumbo-sacral region occur frequently in persons who have never had any symptoms of back-ache and that some of these variations are very marked and severe. They also occur in persons who lead an active life and who work hard. It is probable that these variations predispose to back-ache, but that posture, muscle relaxation, and ligamentous strain are the actual causes.

REFERENCES

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2. O'Reilly: The Lumbo-Sacral Region. Journal A. M. A., Vol. 77; October 29, 1921.
3. Moore: Sacralization of the Fifth Lumbar Vertebra. Journal Bone and Joint Surg., Vol. VII, No. 2, 1925.

DISCUSSION

Dr. A. Bruce Gill, Philadelphia: These conditions of abnormalities of the lower portion of the spine have long engaged the attention of orthopaedic surgeons and roentgenologists. They are of very common occurrence, and, indeed, they are so frequently found in individuals who have in no way suffered from symptoms referable to them that some roentgenologists have ceased to call attention to these abnormalities in their reports unless for some particular reason. How shall we determine, therefore, whether or not certain symptoms, chiefly pain and tenderness, are due to these skeletal variations? Probably the most common of these conditions is spina bifida occulta, occurring in the upper sacral segment. It certainly occurs in very many persons who do not have any symptoms that could possibly be referred to it, and indeed it is difficult to see how it should ever be capable of producing symptoms.

It would seem, therefore, that we should be very guarded in our interpretation of the significance of many of these abnormalities and extremely slow to advise surgical operation for the relief of symptoms which may or may not be due to them.

I think we can agree with Dr. O'Reilly that some of these conditions constitute

a mechanical defect in weight-bearing or in freedom of movement of the spine. But nature so compensates for this that the individual lives for many years, or during all his life, without suffering or disability. Under an acute or under long-continued strain compensation may break and pain and disability arise, but even then we might be uncertain as to the continuity of cause and effect. When these defects are discovered early in the life of the individual we certainly could not be justified in any radical treatment, because we do not at present know that such defects would ever produce symptoms, or when and how they might do so. In our present state of ignorance we are largely confined to the treatment of such symptoms as may arise, rather than to any clean-cut treatment of underlying conditions of whose *modus operandi* we are ignorant.

Dr. J. T. Rugh, Philadelphia: I merely want to add my appreciation of the demonstration which we have had and to call attention to one other factor that has proved of considerable importance in a number of cases which I have treated, especially in adults: that is, the relative size of the sacro-iliac articulation. Careful radiograms in cases of low back pain will, in some instances, show a greatly lessened size of the articulation between the sacrum and the ilium, which, under stress in the case of the female during childbearing, or, in the case of other individuals, with increase in weight as the years go by, is not sufficient to carry the strain of function or the demands upon it by these conditions. I have found it of a great deal of importance and it is a condition anatomically which must be met either by mechanical or surgical means in later life.

One word in regard to the point mentioned by Dr. Gill, I think, is of utmost importance, that is the prevention of the onset of these conditions. If these can be recognized in early life the treatment of the child by proper gymnastic work and the preservation of the proper muscular balance is the best safeguard against the onset of these otherwise extremely troublesome conditions.

Dr. Z. B. Adams, Boston: When you observe these peculiar abnormalities in the spine, such as a broad transverse process on one or both sides, it seems to me in determining whether it is going to be a disabling factor or not we are taking a good deal of responsibility, because I believe a great many of these deformities are the cause of greater stability and greater strength rather than weakness.

Dr. Archer O'Reilly, St. Louis (closing the discussion): I have not very much to say in closing. I made these studies in adults especially by means of the roentgenogram with the idea of seeing the percentage of abnormalities present in the back that were not backache. I think many of our statistics and our ideas are based on the pictures of patients who had backache. On seeing the picture we base our conclusions upon that as the cause of the pain. I believe that these abnormalities are about as common in supposedly normal individuals as in abnormal. Probably there is some strain or something else that results in backache. I think these are more important from a medico-legal point of view in industrial cases than from a purely orthopaedic viewpoint, because the doctor who does not know much about these cases or these abnormalities in backs that have been injured very often imagines that the injury is responsible for these changes, especially the structural changes that take place, when in reality they may have been there for a long while before the patient was hurt. I really believe that men who are engaged in extra hard work, like mining and that sort of thing, ought to have a roentgenogram of the spine before being employed or before they are put to work. If that were done, those who have congenitally weak points could be given work that would not cause strain on the back and we would be saved a great many complications in medico-legal cases.

CLINICAL CONFERENCE, HOSPITAL FOR THE RUPTURED AND CRIPPLED, NEW YORK, MARCH 26, 1925

THE PRESIDENT, DR. ARTHUR KRIDA, IN THE CHAIR

DR. R. WHITMAN—Skin Transplantation for X-ray Burn of Foot.

Dr. Whitman presented a case of skin transplantation for scar contraction. He said the case was of interest as illustrating the results of an X-ray burn. A needle became imbedded in the calf of a sixteen months' old child and was searched for by fluoroscopy. In about a week an extensive burn appeared, which finally closed in about a year and a half. Dr. Whitman first saw the child a year later when the scar contraction had turned the foot toward varus, with a corresponding bend of the leg bone. This had been corrected by osteotomy of both bones above the ankle. A year later the child, now about four years of age, was again admitted to the hospital for calcaneus deformity, the contracting scar which extended from the upper third of the leg to the middle of the tarsus having drawn the foot upward. This scar was removed with the underlying hard fibrous tissue surrounding the tendon of the tibialis anticus and involving the anterior ligament of the ankle so that the joint itself was widely opened in forcing the foot downward. The space was filled by a flap from the other leg. This was separated on the ninth day and, in spite of the poor nutrition of the surrounding scar tissue, had in great part united, now less than two weeks after the operation.

The case was presented to illustrate the danger of prolonged exposure in fluoroscopic examination.

DR. P. W. ROBERTS—Further Report on a Case of Astragalus Graft Reconstruction of Head of Femur.

Dr. Roberts presented a child whose operations and radiographs were reported upon at the last Conference. She had been walking two weeks in a Thomas knee brace. It was observed that she had free motion at the hip joint and the graft appeared to be firmly consolidated with the femur. A roentgenogram taken the previous day showed maintenance of the normal density of the astragalus. Weight-bearing will not be permitted for about six months.

DR. K. HANSSON—The Application of Low Tension Currents.

The suspicious doubt about electricity as a therapeutic agent expressed by most of the best medical men is probably due to the excessive claims of so-called electrotherapeutists. These specialists base their work on a knowledge of electricity rather than upon a knowledge of general medicine and become electricians practising medicine instead of medical men utilizing electricity to obtain a certain effect. During the last epidemics of poliomyelitis and during the late war much has been written for and against the use of the so-called low tension currents. The action of these currents as based on our knowledge of approved physiology and pathology is as follows:

1. *Galvanism:* Unmodified galvanic current is a direct, continuous, unidirectional current, usually obtained from dry cell batteries or from the street current with the

interposition of resistance. It is applied in two ways: continuous galvanism and interrupted galvanism.

A. Continuous Galvanism. This is applied by means of two metal electrodes, usually of the same size, with a pad or several layers of gauze soaked in normal saline or some other appropriate solution. These electrodes are connected to the machine, one becoming the positive, the other one the negative electrode, with positive and negative polarity changes. Great efforts have been made to try to explain what takes place in the interpolar path through the tissues of the body. The result is the medical ionization theory, which is based on what we know of electrolysis or ionic interchange. Many enthusiasts believe that by this method medicine can be introduced through the skin and even through a joint. Experiments have not proved this, but it seems rational to believe that the tissue resistance will produce some heat and thereby benefit, at least temporarily, such conditions as sciatica. The softening effect around the cathode is made use of when it is desirable to loosen up scar tissue.

B. Interrupted Galvanism. If a large electrode is applied over the brachial plexus and a small hand electrode is applied over the motor point of the biceps muscle on the same side, and these electrodes are connected with a galvanic battery, there occurs one contraction of the biceps at the make and one at the break of the current. These contractions are rapid and vigorous. Even if the musculo-cutaneous nerve is cut there will still be a contraction at the make and break, but now the contraction is slow and sluggish. Hereby we conclude that the galvanic interrupted current stimulates both the nerve end point and through the muscle fibers. Thus the interrupted galvanic current suggests itself for muscle exercising in cases where muscle atrophy is due to degeneration of the nerve or the muscle tissue. Because of the difference in contraction when the nerve supply is impaired to a muscle and because K.C.C., A.C.C., and A.O.C. K.O.C. in a healthy muscle and reversed in a nerve lesion, the interrupted galvanic current is used in electro diagnosis of nerve lesions.

2. *Faradism:* This is the alternating current obtained from an induction machine. This consists of a galvanic current leading through an interrupter into a primary coil which is in inductive relation to a secondary coil. This current can be modified as to number of interruptions, voltage, and amperage. The voltage and amperage is controlled by the relation of the coils to each other and the number and size of the wiring in the secondary coil. By using few interruptions and few turns of heavy wiring in the secondary coil we have the Bristow coil, which gives a nearly painless contraction. The Faradic current is applied very much like the interrupted galvanic, with one indifferent electrode over some part of the spine and the small hand electrode over the motor point of a muscle. The contraction that results is a consistent, powerful contraction of the muscle. If this kind of current is applied to a muscle without nerve supply there is no response. From this we conclude two things: (1) that the Faradic current stimulates only through the nerve end point; (2) that the Faradic current is useful in diagnosing peripheral nerve lesions. Except for muscle and nerve testing the Faradic current is now mostly replaced by the Bristow coil, the Morse wave generator, or the sinusoidal.

3. *Sinusoidal Current:* We will confine ourselves to the slow sinusoidal current, so called because if the voltage is traced there is a resemblance to a sine or segment of a circle. The slow sinusoidal current is the straight galvanic current, modified by a varying resistance into symmetrical waves with alternating polarity. Because of this reversing polarity of each successive wave, the sinusoidal current gives no polarity

effects. It provokes a powerful contraction, nearly painless because maximum strength of current is gradually approached and gradually receded from. Because of the gradual contraction and gradual relaxation of the slow sinusoidal and its painless application it has a wide field of usefulness. In the interrupted galvanic, the Faradic, and slow sinusoidal currents we have the mechanical agents for producing muscular contractions. We all know that these contractions cause a temporary increase of the circulation and therefore of the nutrition to the muscle, and when repeated a permanent increase in volume, strength, and tonicity. The technique is not an easy one and requires knowledge of anatomy and physiology and experience with application of electricity. It is necessary to know which muscles are wanted and use only enough current to contract these muscles and not their antagonists. There is a great danger in overworking weak muscles and thereby doing more harm than good. We speak of the unipolar method and the bipolar method of application. In the unipolar method a large electrode is placed over the upper part of spine or the brachial plexus in treating upper extremities, or lower spine or lumbo-sacral plexus when lower extremities are concerned, and the small hand electrode is placed over the motor point of a muscle, the motor point being the place where the nerve enters the muscle. In the bipolar method two small electrodes are used, one at either extremity of the muscle. With the proper technique a number of pathologic conditions of the muscular system suggest themselves.

It is dangerous to apply these currents near the heart, which, if stimulated, responds with fibrillation. Neoplasms and acute infections are contraindications. In concluding, I wish to emphasize that these electrical stimulations by no means replace the so-called Swedish movements, by Lovett translated to muscle training, and wherever it is possible to contract a muscle by voluntary impulses no effort should be made to try to replace the normal brain impulse by an electric current.

CLINICAL CONFERENCE, HOSPITAL FOR THE RUPTURED AND CRIPPLED, APRIL 23, 1925.

THE PRESIDENT, DR. ARTHUR KRIDA, IN THE CHAIR

DR. ARTHUR KRIDA—Plastic Operation for Limitation of Motion at Knee Joint.

Dr. Krida presented the case of a man 38 years of age, upon whom he had operated seven months previously. This man had sustained a compound fracture of the left femur at the junction of the middle and lower thirds in an automobile accident ten years ago. A Lane plating operation had been done, and the fracture had united without distortion, but with stiffness at the knee joint.

At the time of examination the patient presented a range of motion of ten to fifteen degrees from complete extension, a long, densely adherent scar on the outer side of the thigh, and a remarkable degree of atrophy of the thigh muscles.

Operation was done with an Esmarch, a long median incision being made. After isolating the rectus femoris, a sharp, anteriorly projecting spicule of bone was chiselled off. The periosteum was rather widely elevated. The tendinous planes of the lateral muscle masses were nipped transversely, and the rectus femoris was divided in a V-shaped manner. The joint was then forcibly flexed to eighty degrees, with the audible rupture

of capsular adhesion. The quadriceps structures were sutured after the manner of Bennett. A plaster-of-Paris dressing was applied with the knee in the flexed position.

The range of motion had been maintained. The patient had been walking without apparatus about three months, and felt perfectly secure about the joint. The thigh muscles had developed satisfactorily.

DR. A. WHITMAN—Bilateral Arthroplasty of Temporo-maxillary Joint.

Dr. Armitage Whitman presented a case of bilateral ankylosis of the jaw. Three years previously the patient had been struck upon the point of the jaw by the seat of a swing, the blow causing a lacerated wound, but no fracture. About three weeks later he began to notice stiffness of the jaw, which gradually increased, until for the past year he has been unable to open the mouth sufficiently to clean the teeth or take a normal bite of solid food.

Male, 12 years. P. E. The patient was in good condition. He presented the scar of the lacerated wound on the point of the chin; otherwise his face showed nothing abnormal. Active and passive movement at the temporo-maxillary articulation was only sufficient to allow separation of the front teeth three-sixteenths of an inch. There was no lateral deviation on attempted motion, so that it was not apparent which, if either, joint was affected. Radiogram showed nothing.

Under general anesthesia the right side was operated upon March 3. A one and one-quarter inch incision was made beginning just in front of the ear, parallel with, and directly over the zygoma. The periosteum covering the zygoma was incised and stripped downward, carrying with it the superior attachments of the external, lateral, and capsular ligaments. On thus opening the joint the cartilage was seen to have entirely disappeared. The situation of the previously existing joint line was barely apparent. A curved gouge was inserted, and with a mallet the coronoid process was removed piecemeal, the gouge following as accurately as possible the line of the glenoid cavity. The removal of the last portions of bone was difficult because of the unexpected depth of the wound, at least an inch and a quarter, and of the continual venous oozing, which was impossible to control. Finally the entire coronoid process was removed, leaving a gap between the glenoid fossa and stump of the neck of at least half an inch. The wound was closed in layers, the skin with silk. This procedure resulted in practically no increased motion in the jaw. Nothing more than a sense of springiness resulted.

One week later a similar operation was performed on the left side. This was very much easier, because of the mobility, which increased as the coronoid was chiselled through. Upon complete removal of the coronoid process and section of the neck as on the opposite side, immediate free opening of the mouth resulted.

The wound healed by first intention. Both operations were followed by considerable swelling and discoloration of the face, and that on the left by subconjunctival hemorrhage. A fluctuating hematoma formed on both sides, which by the end of ten days had completely absorbed. No sign of paralysis or weakness of any of the branches of the facial nerve was observed after either operation.

Voluntary opening of the mouth was immediately possible, so that the teeth could be separated eleven-sixteenths of an inch, an immediate improvement of one half inch. This improvement has persisted up to the present time. As no material was inserted between the stump of the neck and the glenoid cavity the operations should not properly be described as arthroplasties.

News Notes

Dr. Lemuel D. Smith announces the opening of an office for the practice of orthopaedic surgery at 272 Odgen Avenue, Milwaukee.

The American Academy of Physiotherapy held its mid-year meeting at Atlantic City, on May 25 and 26, 1925, under the Presidency of Dr. Frank B. Granger, of Boston.

Among the interesting subjects presented was a paper by Dr. Harry E. Mock, of Chicago, stressing, from a surgeon's standpoint, the value of physiotherapy as an adjuvant to surgery in the rehabilitation of traumatic cases.

The value of diathermy in the treatment of joint tuberculosis and of bone lesions was demonstrated by Dr. Charles P. Hutchins, of Syracuse, N. Y., in a paper entitled "Report of Tuberculous Knee Treated by Physiotherapy," and by Dr. Willis W. Carey, of Fort Wayne, Ind., in a paper on "Diathermy in Bone Lesions."

In a paper on the "Physics of Medicine" Dr. Charles P. Stokes, of New York, reviewed the history and development of molecular physics.

Prof. W. T. Bovie of the Physiological Laboratory of Harvard University delivered an address liberally illustrated with lantern slides on the "Effect of Light on Growth and Development," in which he discussed the modern physics of light with particular reference to the ultraviolet rays.

Two papers which dealt with the therapeutics of ultraviolet light were those of Dr. Charles R. Brooke, of New York, on "The Value of the Ultraviolet Rays in the Treatment of Nasal and Oral Conditions," and that of Dr. Frank A. Davis on "The Blood Chemistry and Results of Ultraviolet Ray Therapy in Certain Tuberculous and Other Cases."

One of the outstanding features of the meeting was the symposium on "Electro-Surgical Methods," which Dr. Howard A. Kelly characterized in his paper as "The New Surgery." He described the technique by which a cutting operation is facilitated, hemorrhage controlled, and the lymphatics are sealed by the use of electrothermic methods. He emphasized that by these methods shock was diminished, the time of the operation greatly shortened and the risk of infection markedly decreased.

Other papers covering the subject were the following: "Electrocoagulation in Surgery," by Dr. William D. McFee of Boston, Mass.; "The Present Status of Electrothermic Methods in Surgery," by Dr. William L. Clark of Philadelphia; "Endothermy: The New Surgery in Accessible Cancer and Pre-Cancerous Conditions," by Dr. George A. Wyeth.

Among others who contributed to the program were Dr. Walter C. Barker, who read a paper entitled "Diagnostic Value of X-Ray Examination of the Gall Bladder after the Intravenous Injection of Tetraidophenolphthelein"; Dr. Eberhard of Philadelphia who gave a lantern demonstration on "Nonsurgical Biliary Drainage"; Dr.

H. E. Stewart who reported his experiments with "Diathermy in a Case of Pneumonia Following Typhoid and Complicated by Diabetes"; Dr. H. C. Westervelt, who spoke on the subjects covered under the name of "Backache," and Dr. Robert E. Peck of New Haven who read a paper entitled "A Plea for the More General Use of Hydrotherapy by Physiotherapists."

The American Academy of Physiotherapy will hold its next annual meeting October 15 to 17, 1925, at the Copley-Plaza Hotel, Boston.

Clinical demonstrations in physiotherapeutic technique, including electrosurgery, will be given in the Boston City Hospital.

All members of the profession are cordially invited to attend this Convention.

Among the subjects to be presented, and those who are expected to participate in the program are:

Electrophysics, by Prof. Duane of Harvard; Treatment of Sprains, by Dr. Charles P. Hutchins; The Curative Workshop, by Dr. Fred H. Albee; Electrosurgery, by Drs. William D. McFee, William L. Clark, and Grant E. Ward; Galvanism in Neurology, by Dr. James MacPhee; The Aftercare of Fractures, by Dr. Harry Eaton Stewart; Hydrotherapy, by Dr. Robert E. Peck; Taking Things for Granted, by Dr. Burton B. Grover; Intestinal Stasis and Toxemia, by Dr. William Seaman Bainbridge and Sir William Arbuthnot Lane; Application of Clear Quartz to Physiotherapy, by Dr. E. R. Berry; Indications for the Use of X-ray in the Treatment of Breast Tumors, by Dr. Walter C. Barker; Some Reasons for the Delay of the Correlation of Physiotherapy with General Medicine and Surgery and the Specialties, by Dr. Charles F. Stokes; The Rationale of Fraction X-radiation Therapy, by Dr. J. Douglas Morgan.

The British Orthopaedic Association will hold its annual meeting on October 23rd and 24th, 1925, at Manchester.

The President, Sir Robert Jones, K.B.E., C.B., has arranged the following provisional programme for the scientific sessions:

FRIDAY, OCTOBER 23, 1925.

MORNING SESSION
(At the UNIVERSITY MEDICAL SCHOOL, Anatomy Theatre.)

9.30 a.m. Presidential Address.
10.00 a.m. Discussion on "Fractures in the Region of the Ankle Joint." Introduced by Mr. HARRY PLATT.

AFTERNOON SESSION
(At the ANCOATS HOSPITAL.)

2.15 p.m. Operations.
Demonstration of Patients.
Remedial Demonstrations in the Gymnasium.

SATURDAY, OCTOBER 24.

MORNING SESSION
(At the UNIVERSITY MEDICAL SCHOOL, Anatomy Theatre.)

SATURDAY, OCTOBER 24. *(Continued)*

9.30 a.m. Short Papers:—

1. "Renal Rickets." Dr. G. ASHCROFT (by invitation).
2. Demonstrations of dissections and preparations, illustrating:—
   (i) Surgical Anatomy of Peripheral Nerves and Sympathetic Nervous System.
   (ii) Injuries of the Cervical Spine.
   Professor J. S. B. STOPFORD and Mr. G. JEFFERSON
   And other Papers.

AFTERNOON SESSION

2.00 p.m. Visit to the Royal Manchester Children's Hospital, Pendlebury, Manchester.

BOOK REVIEWS

THE PRINCIPLE OF EARLY ACTIVE MOVEMENT IN TREATING FRACTURES OF THE UPPER EXTREMITY. J. W. Dowden, M.D., F.R.C.S.E., Surgeon to Chalmers Hospital; Late Surgeon to the Edinburgh Royal Infirmary. Edinburgh and London: Oliver and Boyd, 1924.

The author states that he hopes to demonstrate by means of illustrations the results he has obtained by applying the principle of early active movement in the treatment of fractures of the upper extremity. He seeks to guide the general practitioner in the use of this early active movement treatment and has purposely omitted reference to operative and other forms of treatment to be called for in exceptional cases.

In the introduction the author seeks to state the meaning of early active movement in the treatment of practically all injuries. Here he stresses ably the accepted attitude of surgeons and masseurs toward massage and active movements. He says massage and passive movement are better than immobilization alone, but active movement is far superior to passive movement.

After reading this attractively gotten-up monograph the reviewer feels that he has listened to a special pleading. He has been led by an intelligent enthusiast to see a portion of a picture, but feels that the author has not demonstrated his case because it is impossible to adequately demonstrate by illustrations "results of fracture treatment." Moreover, such a monograph will be a very treacherous guide for the average general practitioner. That the author has partially demonstrated what the employment of early active movement will do for certain fractures is true, but the treatment of a fracture is a very complicated and not a simple thing. Neither the employment of early active movement alone, nor the employment of some form of immobilization alone, nor the direct operative treatment alone, is ever adequate in the care of a fracture. The reviewer believes that the employment of active movement, at a much earlier date than has commonly been the case, in the course of the treatment of every fracture of a long bone, is highly desirable.

The monograph is valuable in that it attempts to show what can be accomplished by early active movement. It is helpful, stimulating, and at the same time so partial, so unsatisfactory, that we close its pages wishing that we might have an hour's chat with the author and learn if after all he does not believe very much as we do in America,—namely, that it is the combination of methods adapted to each case rather than any one method that is most desirable. No general practitioner in America with whom the reviewer is acquainted is competent to follow the author's treatment with any of the suggestions the author has made.

J. B. Mennell of London, in his "Massage: Its Principles and Practice," presents the case of early active movement in the treatment of fractures.

The author of this monograph has attempted a very dangerous thing,—the popularizing on too narrow a foundation of a fundamentally important principle. The book is worth reading, but with always the query after each case is described, "I wish I could examine that case myself and know more of the actual limitation of movement, the disability, the falling short of normal performance." There are comparatively few cases of fracture to which the early active movement treatment alone is strictly applicable. Early active movement instituted with all the precautions which the author indicates is a remarkable adjuvant to other principles of treatment in fractures of bone.

Current Literature

FRACTURES AND DISLOCATIONS

UNUSUAL DISPLACEMENT OF THE PATELLA, PATELLAR TENDON, AND TIBIAL TUBERCLE CORRECTED BY OPERATIVE REPOSITION. By Louis A. O. Goddu. *Boston Med. and Surg. Jour.*, April 23, 1925, p. 795.

This is a description of a very unusual traumatic disability of the knee. An ingenious operation was performed with improvement in the condition of the patient.—*F. G. Hodgson, M.D., Atlanta, Ga.*

TREATMENT OF CHRONIC RECURRENT DISLOCATION OF SHOULDER BY CRUCIAL CAPSULAR PLICATION. W. L. Keller. *Annals of Surgery*, January, 1925, p. 143.

Keller reports eleven cases treated by plication of the anterior portion of the capsule, which he explores by the axillary route along its posterior margin and directly over the humeral head. The capsule is freed from the axillary contents when a crucial incision, one limb upward and one crosswise, is made in it. The margins of these incisions are overlapped by a type of mattress sutures reducing the laxity of the capsule to a minimum. The operation was conceded a failure in one case. The rest have been successful.

As nine of the cases were operated upon in 1923 and 1924 it is possible that the chapter on recurrences is not permanently closed.—*C. A. Parker, M.D., Chicago.*

TEAR-FRACTURE OF THE ANTERIOR SUPERIOR SPINE OF THE ILIUM. W. Kuehnast. *Arch. f. Orthop. und Unfallchir.*, Vol. 23, No. 4, March, 1925, p. 460.

The anterior superior spine can be torn off, though rarely, in children. This may occur in the course of gymnastic exercises and happens when an unsuitable movement is made in the attempt to regain the balance while falling. The symptoms are limping, stiffness, and prevention of motion in all directions; there may even be a total loss of motion of the affected leg, tenderness over the region of the spine, its dislocation, possible crepitation and movability of the torn-off fragment. The principal cause lies in the function of the tensor fascia lata.—*A. Gottlieb, M.D., Los Angeles, Calif.*

ELBOW FRACTURES AND DISLOCATIONS. By Irwin E. Siris. *Surgery, Gynecology, and Obstetrics*, May, 1925, p. 665.

This paper gives a careful classification of elbow-joint injuries. The history, diagnosis, and treatment of each type are considered in separate paragraphs. Stress is laid upon functional result rather than anatomic apposition, and upon splinting the joint at

an acute angle, early active motion and the use of the fluoroscope with careful manipulation in place of open operation for the reduction of elbow fractures and dislocations in children. There are twenty-four case reports and two tables for comparative purposes. The paper is illustrated with forty-eight half-tone cuts of excellent quality. Dr. Siris' summary cannot be improved and it is here quoted.

"*Summary.* Children have excellent reparative powers in fractures. Perfect anatomic approximation of the fragments is not always essential for functional recovery. Displacement and overriding of fragments will often result in a good functional limb and complete restoration of the bony contour. Anatomically restored elbows may be lacking in mobility unless they are treated judiciously. The best results are obtained by immediate reduction under an anaesthetic with the aid of the fluoroscope. Partial immobilization with adhesive and early active motion will reduce swelling, increase muscular tonicity, and prevent muscular spasm, exuberant callus, Volkmann's ischaemic paralysis, and myositis ossificans. Passive motion with or without an anaesthetic and active massage retards progress. Musculospiral and ulnar paralysis accompanying and following fractures about the elbow is not always permanent. Myositis ossificans will disappear with the discontinuation of trauma to the brachialis anticus. Open operations in children are not indicated, as good functional limbs will follow displaced fragments, and infections are very prone to follow open operations. Compound fractures are best treated by débridement, Carrel-Dakin sterilization, suspension in flexion by adhesive or in a flexed Thomas splint, to be followed by secondary suture or granulation, with the institution of early active motion."—*H. A. Pingree, M.D., Portland, Maine.*

ABDUCTION TREATMENT OF FRACTURE OF NECK OF FEMUR. R. Whitman. *Annals of Surgery*, January, 1925, p. 374.

In a well illustrated and brief article Whitman very definitely, if not dogmatically, expounds his well-known ideas of the proper care of fractures of the neck of the femur by the abduction spica, and concludes his robust polemic with the following pungent paragraph: "At the present time the opposition to the general adoption of the abduction treatment is rather of the nature of inertia than of loyalty to the ancient ritual, the chief objection being, apparently, that its application, particularly the adjustment of a secure and comfortable plaster spica, requires more skill and experience than is possessed by the 'average worker.' This proposition, in effect, that incompetence should disqualify the treatment rather than the surgeon, however logical under the old dispensation, is no longer tenable. For traditional authority having been disproved and discredited can no longer assure immunity for inadequacy, inefficiency, and neglect."—*C. A. Parker, M.D., Chicago.*

SUBTROCHANTERIC OSTEOTOMY IN THE TREATMENT OF CONGENITAL DISLOCATION OF THE HIP. Froelich. *Revue D'Orthopédie*, 1925, 23, 309.

Froelich is convinced that in younger patients bloodless reduction is the operation of choice. In older cases, however, this procedure is not possible. Many of these cases have pain and adduction deformity in adult life. It is possible to relieve the symptoms by a simple subtrochanteric osteotomy of the femur. This operation was done by Kirmisson in 1892 and two cases were reported by Froelich in 1903. Recently it has been rediscovered and is now known as the bifurcation operation of Lorenz.

It is used only in patients who have difficulty in walking and pain. The osteotomy is performed at a point opposite the center of the acetabulum and may be oblique or transverse. The lower fragment is then directed into the acetabulum and the limb immobilized in plaster in a position of 45° abduction, slight flexion, and slight internal rotation. Nineteen cases are reported, the first having been operated upon in 1902. Upon the whole, the results have been very satisfactory. The pain is relieved, the lordosis disappears, and the limp is lessened. The shortening, however, is increased from two to four centimeters. For this reason the results are more satisfactory in bilateral cases. The best results were obtained in cases where the two fragments approach the acetabulum together and unite in that position. Delayed union (7 months) occurred once, and in two instances the fragments projected in Scarpa's triangle and it was necessary to remove the exostosis at a subsequent operation.—*J. Albert Key, M.D., St. Louis.*

OSTEOMYELITIS

OSTEOMYELITIS IN CHILDREN. Carl C. Chatterton. *Minnesota Medicine*, February, 1925, p. 91.

This paper concerns itself principally with the pathology of acute osteomyelitis in children. Destruction is believed to depend principally upon the type and virulence of the infection, and to a lesser extent upon the condition and anatomic shape of the bone. The types of infection met with in this condition are the staphylococcus aureus, staphylococcus albus, pneumococcus, and occasionally bacillus infections, such as typhoid bacillus.

From the roentgenograms the author finds a striking similarity in the untreated cases of bone infections in children, the progress and destruction being practically always near the epiphyseal line, the subsequent damage being due to circulatory changes, edema and products of bacterial activity.

Diagnosis and treatment are briefly discussed, and early drainage urged. The author recognizes the necessity of hospitalization when irrigation treatment is to be successful. In the later stages, when sequestration has occurred, radical operation is advised. The prevention of deformity by traction and splinting in all acute cases is emphasized.

The author's conclusions are:

Acute infective osteomyelitis is essentially a disease of childhood and adolescence. It is absolutely a surgical condition. The power of bone regeneration in children is almost marvelous. Early and correct diagnosis for ideal treatment is essential. Early wide-open complete drainage near the end of the bone is the successful method of treatment.

The article is well illustrated with nine illustrations.—*Henry W. Meyerding, M.D., Rochester, Minn.*

HAEMATOGENOUS OSTEOMYELITIS. By William T. Doran and Leslie Brown. *Surgery, Gynecology, and Obstetrics*, May, 1925, p. 658.

The report is taken from the Surgical Service of the Bellevue Hospital of the last four years. On account of the age limit none of the patients was over twelve and one-half years of age.

There are six tables showing comparative figures under the headings of age, organism found, part involved primarily, bone affected, treatment, duration and progress.

There are eight skiagrams showing bone lesions during the course of treatment. The report seems very impartial and records the bad results as well as the good. The conclusion of the authors follows:

Conclusion: The necessity of early diagnosis and proper surgical treatment cannot be too vigorously advocated. Too few of the cases in this series were recognized as osteomyelitis in the early stage, when proper surgical intervention would have promised a short convalescence. The majority of these that did receive early care recovered within four months on the average. Early surgical treatment is the only means of reducing the morbidity and mortality. If sufficient drainage is instituted in the early stages destruction of the cortex is avoided and convalescence is short. If the time from onset to operation is measured in hours, the convalescence is measured in weeks; if measured in days, the convalescence is measured in months or years.—*H. A. Pingree, M.D., Portland, Maine.*

VERTICAL EXTENSION OF THE LOWER EXTREMITY IN ACUTE OSTEO-ARTICULAR AFFECTIONS OF THE HIP. Curtillet and Tillier. *Journal de Chir.*, 1925, 25, 524.

In osteomyelitis or purulent arthritis of the hip, the authors find that vertical traction of the affected extremity gives adequate drainage, cleanliness, and comfort to the patient. To prevent ankylosis in a position of 90° flexion the extremity is lowered as soon as the wound is clean. They report eight cases of acute hips in which this treatment was used. All were cured in a remarkably short time except one patient who refused to continue treatment and died out of the hospital.—*J. Albert Key, M.D., St. Louis.*

NEOPLASMS

BONE TUMORS. By Barney Brooks, *Southern Medical Journal*, April 25, 1925, p. 274.

The author divides bone tumors into three groups: 1, clearly benign tumors; 2, clearly malignant tumors; 3, tumors intermediate between groups 1 and 2. Examples in group 1 are osteoma, chondroma, and benign bone cyst. These usually present no difficulty in diagnosis or treatment. Group 2 contains tumors which produce distinct metastases, such as periosteal sarcoma. The prognosis in these tumors is extremely grave, no matter how radical the treatment. The third group of tumors invades and destroys adjacent tissues, but does not produce metastases. The existence of this group of cases is not generally appreciated and the treatment instituted is often more radical than necessary for cure.

The author divides bone sarcomata into two groups—one producing metastases and of hopeless prognosis, and others which may infiltrate and destroy adjacent tissues but form no metastases, and may be cured by complete local removal.

Eight illustrative cases are reported in detail. The author concludes that the clinical differentiation of these cases is difficult and often impossible. Exploratory incision for diagnosis or local operative removal does not influence the prognosis. Every means available, including exploratory incision and removal of tissue for micro-

scopic diagnosis, should be instituted to determine if the bone tumor is of the metastasizing or non-metastasizing variety. In a given case, therefore, of sarcoma of bone, local excision or amputation is to be chosen according to which gives the best immediate functional result.—*F. G. Hodgson, M.D., Atlanta, Ga.*

Six Cases of Foreign Bodies of Traumatic Origin in the Elbow. Pigeon, Bernard, and Jonathan. *Bulletins et Mémoires de la Société Nationale de Chirurgie*, February 14, 1925, p. 140.

Case 1. A soldier on trying to start an aeroplane propeller felt a violent pain on the outer side of his elbow. Roentgenogram showed a shadow behind and below the external condyle, and at operation a piece of cartilage eight by eighteen millimeters in size was removed. It presumably came from a fracture of the external condyle. A good result was obtained.

Case 2. Two cartilaginous bodies were removed from the olecranon fossa of a Zouave soldier three months following an injury which had caused limited motion in the joint. They seemed to have come from a chip fracture of the condyles. Function of the elbow was much improved, although extension remained slightly limited.

Case 3. Following an injury to the right elbow, a soldier suffered intense pain over the olecranon. Motion possible from eighty to one hundred and twenty degrees. Roentgenogram showed a shadow posterior to the condyles. A piece of cartilage was removed from the olecranon fossa, evidently coming from a fracture of the condylar margin.

Case 4. On trying to lift a heavy motor a soldier felt a sudden sharp pain in the outer part of his elbow. Roentgen examination showed a shadow between the external condyle and the head of the radius. Improved in function by physiotherapy.

Case 5. Some foreign bodies the size of large coffee grains were demonstrated in the outer part of an elbow following a grenade wound, but function in the joint was practically normal.

Case 6. A flat piece of cartilage about the size of a dime was removed from between the external condyle and head of the humerus a few days after a fall on the flexed elbow, confirming the diagnosis of chip fracture of the condyle. Good function obtained.

In four of these six cases the loose bodies occurred after injury by muscular violence only. The question is raised as to whether the articular surface may not have been abnormal from arthritis or from osteochondritis dessicans in such cases.

Loose bodies in the elbow are said to be rather rare, Clavelin finding only twenty in the literature.—*William Arthur Clark, M.D., Pasadena.*

OPERATIVE PROCEDURES

Arthroplasty of the Knee by Transverse Patellar Route for Fibrous Ankylosis. Alglave. *Bulletins et Mémoires de la Société Nationale de Chirurgie*, March 28, 1925, p. 379.

This paper is a demonstration of an anatomic specimen to show the technique of an operation done first by this method a few months before.

First step: A J-shaped incision is made with the long arm along the external aspect of the knee and the curve down around the patella. The patella is cut through at the junction of the lower and middle third.

Second step: the knee is placed in hyperflexion, breaking up all adhesions and the anterior crucial ligament.

Third step: The upper fragment of the patella is now liberated from the condyles and all the articular surfaces smoothed off. The femur should be exposed well up under the quadriceps to insure good motion.

Fourth step: A flap of fascia lata is cut from the outer side of the thigh, preserving a broad pedicle distally next to the condyle, and turned over to completely cover the condyles. The flap should have a good layer of fat taken with it.

Fifth step: The two fragments of the patella are then brought together and sutured with linen and a wire encircling suture, and the knee placed in a splint for about six days. Motion is then begun.—*William Arthur Clark, M.D., Pasadena.*

Cineplastic Disarticulation of the Elbow. Bosch Arana. *Presse Médicale*, January 17, 1925, p. 67.

The South American surgeon here describes his ingeniously devised procedure for making available for prostheses arms that have been amputated with short stumps below the elbow. Essentially it involves the removal of all useless portions of the stump, and the utilization of the biceps tendon to fashion the loop. The main difficulty, however, in this problem is to furnish a satisfactory covering of the loop. It is useless to attempt a description of this part of the operation without the aid of the illustrations that accompany the original article. It requires a special, carefully designed incision, and an equally definite plan of closure. Those interested in this branch of surgery will be repaid by an examination of the original article.—*Roades Fayerweather, M.D., Baltimore, Md.*

Arthroplasty of the Knee. Cunéo. *Bulletins et Mémoires de la Société Nationale de Chirurgie*, March 7, 1925, p. 240.

In judging results of arthroplasty the nature of the lesion for which the operation was done should be given due consideration. The type of ankylosis, fibrous or bony, the angle of the joint, the periarticular lesions, the contractures of ligaments, are all matters of great importance.

In bad cases it may be necessary to cut the lateral ligaments and the crucial ligaments. This, of course, might cause lateral instability, but to guard against such a condition a projection should be preserved on the tibia to fit into a groove between the femoral condyles.

The author uses Putti's technique, including a free piece of fascia lata to cover the condyles. The prominent curve of the condyles is reduced somewhat in front and the patella is shaved down a little thinner in order to insure better function.

After-treatment is most important. The psychology of the patient, his willingness to co-operate and ability to stand the pain of motion, all are factors of success.—*William Arthur Clark, M.D., Pasadena.*

AMPUTATIONS IN INDUSTRIAL SURGERY. W. L. Estes. *Annals of Surgery*, January, 1925, p. 164.

This article is a practical up-to-date treatise on the subject of amputations in industrial surgery and is an illuminating discourse on conservative surgery in this type of accidents. It does not read like a student thesis, but more like the careful utterance of a mature surgeon who has had to cope with conditions as they are in industrial surgery, rather than what they might be limited to in a teaching institution. It is too long and too full of valuable points to be abstracted. It should be carefully read to be properly appreciated. In a total of 727 major amputations there were thirty-one deaths. When it is recalled that these amputations were for traumas and that 223 of them were of the thigh, it is evident that industrial surgeons in general will have to go some to follow such a pace.—*C. A. Parker, M.D., Chicago.*

ARTHROPLASTY. M. S. Henderson. *Minnesota Medicine*, February, 1925.

Arthroplasty is defined as "the plastic operation on an ankylosed joint to permit motion with stability." The author has reviewed the arthroplasties performed at the Mayo Clinic during the past fourteen years, and emphasizes the importance of careful selection of joints to be mobilized. Only a small percentage of patients coming to the Clinic with ankylosed joints had arthroplasty performed.

The jaw, elbow, knee, and hip were found to be the most suitable for arthroplasty, in the order named. The shoulder is seldom operated upon, due to the fact that the movement of the scapula on the thorax compensates the lost motion of the stiff shoulder. Recently experience in arthroplasty of the knees has been so encouraging that it is now considered more suitable than mobilization to the hip.

The careful selection of patients is an important consideration in obtaining successful results. Those who are eager and enthusiastic, courageous and persistent, in spite of discomfort, and who cheerfully co-operate with the physiotherapist during convalescence obtain the most satisfactory results. Children are usually unsatisfactory subjects for arthroplasty.

The joints which give the best results are those with bony ankylosis, following acute infections. Pain, tenderness, thickness, and local heat are dangerous signals, and should be absent for a year before operation. Experience indicates that poor results follow surgery when it is attempted before the infection has been quiescent for a sufficient length of time. Callus formations producing ankylosis should be allowed to harden and become mature before arthroplasty is attempted; the callus-forming ability of these joints is great and dooms surgery to failure if it is attempted too soon. The type of infection in monarticular activities, aside from tuberculosis, appears of little importance. Gonorrheal arthritis coming to ankylosis seemed to do well when properly selected as to time following infection.

The author lays emphasis on the following points concerning operation:

1. Avoid the tender, painful, thickened, warm ankylosed joint, whether following sepsis or trauma.

2. Avoid the case in which there is multiple joint involvement, if the process is still active in other joints.

3. Avoid tuberculous ankylosed joints. The patient with ankylosis in both knees is entitled to arthroplasty, other things being equal, as is the patient with two stiff hips alone, or with two stiff knees also.

Unless the ankylosed joint interferes seriously with the patient's occupation, surgery should be undertaken only after a most careful consideration, especially when the joints are in suitable position. Many patients lose their enthusiasm to have arthroplasty performed when they realize that the economic loss which they incur because of loss of time is very great in comparison to the small benefit which they derive from mobility of the joint.

In discussing the operative technique he refers, because of lack of time, to the various principles followed by Campbell, Baer, Putti, and MacAusland. He points out that in the hip, knee and elbow the interposition of soft tissues is essential, while in the jaw it is not. In the elbow the Campbell and MacAusland technique have been used. The splitting of the olecranon gives excellent exposure and the fragments are held in position by a beef bone screw.

Recently the Smith-Petersen incision has been used in operating upon the hip, although the Murphy technique of chiselling off the trochanter has given good exposure and has been found satisfactory. The difficulty of obtaining satisfactory pedicle flaps has led to the use of fascia lata transplants. In the knee the Putti technique has been closely followed and the fascia lata transplants used rather than the pedicle flaps. The author notes, however, the excellent results obtained by Campbell, who uses one large condyle instead of reshaping both condyles.

After arthroplasty immobilization is maintained until the clotting is sufficiently organized and bleeding has ceased. Motion is begun in from five to seven days, while the leg is held in the Jepson splint, care being taken not to cause too much pain and discomfort, thereby losing the confidence of the patient. In the knee and hip, gentle traction during fixation appears to give more satisfactory results.

During the ambulatory stage a jointed knee brace is necessary to maintain stability. From six to nine weeks after the operation, if there comes a period where motion is unsatisfactory, a manipulation under anesthesia and the assuring of the patient that motion is present, will lead to increased efforts on his part.

One hundred and forty-two cases have been operated upon since 1910. Of these, one hundred and three gave definite information, while the remaining thirty-nine had records which were untrustworthy. The postoperative shock was a negative factor in these cases. Seven infections were noted, six in the hip and one in the knee, and these were probably due to the lighting up of old infections. The author notes the difficulty in grading results, and for simplicity's sake he gives the following table:

RESULTS OF ARTHROPLASTY IN 103 OF 142 CASES

Joint	*Excellent*	*Good*	*Fair*	*Poor*	*Total*
Elbow	12	7	5	6	30
Jaw	20	2	4	4	30
Hip	3	9	8	7	27
Knee	4	4	3	2	13
Shoulder	1	2	0	0	3
Total	40	24	20	19	103
Per Cent.	38	23	19	18	

Excellent and good in 64 (62 per cent.)
Satisfactory in 84 (81 per cent.)

Most of the patients were in the third or fourth decade. Seventy-four were female and sixty-eight male.

The conclusions are drawn as follows:

1. Each case is considered separately, the joint or joints involved, the type of infection, the type of the patient and his economic status, all being prominent factors in the decision as to whether or not arthroplasty is to be undertaken.

2. Since 81 per cent. of the one hundred and three patients treated obtained satisfactory motion in previously ankylosed joints, and since 64 per cent. obtained good or excellent results, arthroplasty would seem to be a justifiable procedure.

3. Failures to obtain good results from arthroplasty are mostly attributable to a poor selection of cases.

4. The cases in the series were observed during the last fourteen years. There is no doubt that with the present advances in technique and experience in the selection of cases, the percentage of excellent results could be increased.—*Henry W. Meyerding, M.D., Rochester, Minn.*

THE SUBSTITUTION OF THE ERECTOR SPINAE FOR PARALYZED GLUTEAL MUSCLES. An Operation for Stabilizing the Hip. By Philip H. Kreuscher. *Surgery, Gynecology, and Obstetrics*, May, 1925, p. 593.

Dr. Kreuscher has described an operation for the utilization of a part of the erector spinae muscle in place of paralyzed gluteal muscles for an improved control of the lower limb. About six inches of the outer half of the erector spinae with a pedicle at the upper end is employed. From the free extremity silk tendons are pressed down between the glutei and the skin and are fastened round the femur and in a hole bored through the great trochanter. Another strand of silk is run from the trochanter to the crest of the ilium as an additional security against adduction. The thigh is held at first by gypsum and later by a removable splint in abduction for some months. This fixation is followed by massage and active motion. He reports one case that was benefited to a marked degree. Seven very excellent illustrations accompany the article.—*H. A. Pingree, M.D., Portland, Maine.*

MISCELLANEOUS

COXA PLANA IN ITS DEFINITIVE FORM. Mario Camurati. *Chir. Org. di Movimento*, March, 1925, p. 213.

Camurati reports observations in three cases of coxa plana after a period of more than ten years.

FIRST CASE: Boy, eight years of age, seen on January 16, 1913. Atrophy of right leg; pain in hip. Abduction and internal rotation impaired; a positive limp. Trendelenburg positive on the right side. Roentgenogram showed typical flattening of the head of the femur. Examination on June 16, 1924, showed slight atrophy of the right leg. The patient stepped heavily with the right foot. There was slight Trendelenburg; no pain around the hip. Abduction and internal rotation limited to one-third normal range; flexion also limited. Roentgenogram showed the femoral neck short; marked coxa vara; head of femur flat and ovoidal in shape.

SECOND CASE: Boy, six years of age, seen December 2, 1912. Atrophy of left limb; Trendelenburg positive. The hip was painful and there was a limp. Abduction and external rotation limited to one-half normal range. Radiogram showed irregular epiphyseal line and fragmentation of cephalic nucleus. Examination twelve years later, June 16, 1924. Considerable atrophy of right limb; normal gait, negative Trendelenburg. Radiogram showed coxa vara, neck of femur short, head flat.

THIRD CASE: Boy, five years of age, seen May 26, 1911. Right limb; no atrophy. Abduction and external rotation limited; marked limp; positive Trendelenburg. In roentgenogram head of femur appeared very flat. Examination thirteen years later, June 10, 1924. Right limb: no atrophy. Abduction limited. Gait normal. Trendelenburg sign absent. Roentgenogram showed femoral neck short and with varus.—*Felipe Muro, M.D., Farmington, Mich.*

TREATMENT OF SPONDYLOLISTHESIS. Desfosses and Colleu. *Presse Médicale*, January 3, 1925, p. 4.

The dry specimen in the Musée Baudelocque is briefly described, with helpful sketches. What is not referred to by the authors of this short article is that this appears not to be a typical case of spondylolisthesis, in that there evidently has been no actual forward displacement of the body of the fifth lumbar vertebra on the sacrum. It seems, instead, that the fifth lumbar and the first sacral vertebrae have assumed a sharp forward droop, so that the vertical axis here has become horizontal, entraining a marked deepening of the lumbar lordosis. The authors are interested particularly in the bony irregularities of the posterior half of the vertebral arch in the last lumbar vertebra, interpreting them as evidences of an infectious inflammatory condition of earliest infancy. This inflammatory condition they believe to have caused the development of the gross static deformity.

Discussing possible modes of treatment, all surgical measures are dismissed as illogical or impracticable. It is proposed that recumbency in plaster cast would tend to induce gradual correction of the deformity. It is not apparent that the authors have had any experience in treating such conditions in this manner.—*Roades Fayerweather, M.D., Baltimore, Md.*

SPASMODIC TORTICOLLIS. J. M. T. Finney and W. Hughson. *Annals of Surgery*, January, 1925, p. 255.

These authors review the development of operative treatment of this condition and relate their experience in thirty-two operated cases. The origin of many cases still remains obscure. The operation employed is a development of Keen's method, first published in 1891, and has for its purpose a careful resection of the suboccipital, the great occipital, and the third cervical nerves. This requires an extensive and deep dissection of the structures at the back of the neck. They employ an inverted U-shaped skin incision beginning at the back of the sternomastoid muscle two finger-breadths below the angle of the jaw and passing upward along the border of the muscle until it passes in a curve inward to a point two finger-breadths below the external occipital protuberance, whence it is continued down to below the angle of the jaw on the other side. With this flap turned down and the great occipital nerve as a guide, the trapezius and splenius and complexus are cut across and the structures making up the suboccipital

triangle brought to view. At this depth the three posterior branches of the cervical nerves are resected. The results of treatment are thus summed up: "Of our series of thirty-two operated cases, one has not been heard from recently. Of the remaining thirty-one, three are unimproved, sixteen have been improved but not entirely relieved, while twelve have been completely cured. It should be borne in mind that these operations cover a period of more than twenty years, that the earlier operations were very incomplete, and that the operation just described has been developed comparatively recently. It has been used in only a few cases, too few and too recent to enable us to pass final judgment on its merits, but in a sufficient number, we believe, as compared with previously used and less radical methods, to justify its more extended use."—*C. A. Parker, M.D., Chicago.*

Ossification of the Peroneal Tendon or Sesamoid in the Region of its Attachment at the Base of the Fifth Metatarsal. By Louis A. O. Goddu. *Boston Med. and Surg. Jour.*, May 7, 1925, p. 899.

This is a description of a nurse with a sesamoid in the peroneal tendon which was giving symptoms. The bone was removed by operation and the patient relieved. This bone was described by Dwight as the Peroneum.—*F. G. Hodgson, M.D., Atlanta, Ga.*

Curvature of the Radius. André Martin. *Bulletins et Mémoires de la Société Nationale de Chirurgie*, February 14, 1925, p. 136.

The case reported is that of a boy of thirteen, operated upon in 1922 for this deformity. At that time there was a sharp external deviation of the hand, the head of the ulna was prominent, motion in the wrist limited in antero-posterior direction, but exaggerated in lateral direction. Roentgenogram showed the radius shortened, curved outward and backward, its distal articular surface directed somewhat forward. The ulna was normal. Osteotomy of the radius was done in the lower third and the curve corrected. The forearm was immobilized in forced supination for about five weeks. Two years after operation the movements of the wrist were normal and the lower articular surface was no longer directed forward. The epiphyseal line was somewhat narrow, but the diaphyseal curve was gone. Athough a good result was obtained in this case by linear osteotomy through an anterior incision, it seems more logical to do cuneiform osteotomy through a posterior incision. Lenormant has done such a case by cuneiform osteotomy on the posterior lateral aspect of the radius in a case where it was necessary to resect a part of the ulna to obtain correction in severe cases.

In discussion of this paper M. Mouchet said he thought the case reported might have been an old fracture rather than a true case of Madelung's deformity or curvature of the radius.—*William Arthur Clark, M.D., Pasadena.*

Painful Kyphosis and Vertebral Epiphysitis of Adolescence. Mathieu, Massart, and Ducroquet. *Bulletins et Mémoires de la Société Nationale de Chirurgie*, February 28, 1925, p. 220.

In the series of eight cases the principal common findings were: dorsal kyphosis with a long curve but no angulation involving D VII, VIII, IX, and X, pain and tender-

ness and more or less stiffness in the back, rapid growth of the patient, gradual increase in the curve if untreated.

Case 1. Boy of 14. Pain and aching between shoulders, easily fatigued; symptoms disappear on lying down. Roentgenogram in profile showed cuneiform shaped bodies of D VII to XI. No evidence of tuberculosis. Treated recumbent in plaster jackets, the symptoms disappearing and the back gradually becoming straighter. About two years later the symptoms and kyphosis were gone.

Case 2. Girl of 17. Severe kyphosis involving entire dorsal spine accompanied by slight left dorso-lumbar and right upper dorsal scoliosis. Pain so bad that she was considered as having a tubercular spine and was sent to Berck, although roentgenograms showed only irregular shape of dorsal vertebrae. On returning from Berck, the diagnosis of tuberculosis not being confirmed, she still suffered with pain in the back and the kyphosis was worse. General condition better.

Case 3. Girl of 14, with round kyphosis and right scoliosis in dorsal region. Had grown rapidly. Aching in back. Roentgenogram showed cuneiform bodies of D VII to IX. Improved in general condition by rest.

Five other cases are reported in detail, all quite similar to the above.

The intervertebral disc was usually thin and compressed at its anterior border so that the edge of the bones often came together. The discs were also irregular and sometimes showed erosion. It is this condition which gives the syndrome the name: vertebral epiphysitis of adolescence. In these cases the epiphyses often develop much earlier than usual. It is probably analogous to epiphysitis of rachitis; in fact, four of the cases reported were clearly rachitic. Other than that the cause of the lesion is not known.

In the discussion of the paper Mouchet calls attention to the similarity between this vertebral epiphysitis and Legg's disease (osteochondritis of the hip) and Köhler's disease of the scaphoid.—*William Arthur Clark, M.D., Pasadena.*

Indications for Treatment of Congenital Talipes Equino Varus. Ombredanne. *Bulletins et Mémoires de la Société Nationale de Chirurgie,* March 7, 1925, p. 251.

There is a period of complete reducibility for club feet which usually terminates at about two weeks of age, although it may be possible to accomplish reduction at twelve or fifteen months, and, on the other hand, a foot may be irreducible at birth. This refers to normal reduction without great violence. If the deformity recurs in spite of careful treatment, it is due to irregular development of the bones. The period following this extends to two years or at the most four years, and is the period of tenotomies, fasciotomies, and other soft tissue work. After this comes the stage when bone work must be done to obtain a correction. Forcible osteoclasis, blind chiseling of the bone, or promiscuous removal of bone is condemned by the author. Surgical work on the bones must have sound reason and rule. "Put back the astragalus in its proper place" is probably the keynote of proper correction. But even this is sometimes not sufficient. Nélaton resected the head and neck of the astragalus to get better correction of the equinus. The author thinks that replacing the astragalus may even be bad because it may cause ankylosis. He makes it a rule never to touch the tibiotarsal joint because it is the most important one in the foot to preserve for walking.

The dorsal external cuneiform tarsectomy of Farabeuf is classical, but it has the disadvantage of shortening the foot and also not correcting the supination. Placing

the wedge removed from outside into an opening on the inner border of the foot to overcome the shortening is suggested, but it is not always possible to do this. If, in addition to the dorsal-external wedge, a second cuneiform osteotomy is done at the subastragaloid joint, the base of the wedge external, the supination will be corrected.

Astragalectomy if done according to the Whitman technique will correct the equinus, but it may be necessary to supplement this operation with external cuneiform osteotomy to correct the varus.

Torsion of the tibia, instead of being primary, may be a secondary deformity due to muscle strain as a result of the deformed foot.

Whatever operation is done one may not draw conclusions as to its efficacy before the child is at least eight years old, because at this age the bones begin to take on permanent form. In general the later the osteoplastic operation the more lasting will be the results.—*William Arthur Clark, M.D., Pasadena.*

CASE OF BUERGER'S THROMBO-ANGIITIS. Ravina and Longchamps. *Bull. Soc. Méd. des Hôp.*, January 8, 1925, p. 9.

This type of Buerger is referred to as intermediate between endarteritis obliterans and Reynaud's disease, having the anatomic lesions in the peripheral arterioles and venules rather than in the larger arteries (intermittent claudication) or in the capillaries. In the case here reported the patient had for several winters had cyanosis of the feet, severe pains, loss of nails, and superficial ulcerations of the toes. Recently he had developed cyanosis and pains in the hands. All these conditions had been clearing up in the summer months. It was determined that his blood contained an excess of sugar and cholesterin. Treatment consisted in administration of sodium citrate by mouth, sodium nitrite subcutaneously, rest, local heat, and bandaging. Improvement was marked; ulcerations healed rapidly; patient was able to walk long distances.—*Roades Fayerweather, M.D., Baltimore, Md.*

ISCHIO-PUBIC OSTEOCHONDRITIS. G. Valtancoli. *Chir. Org. Mov.*, March, 1925, p. 281.

Patient, a male, nine years old, who, following a fall, began to complain of pain on the inner side of right groin, increased while walking. Abduction was limited; all other motions were normal. The roentgenogram of the pelvis showed that the hip-joint was normal, but at the point where the ischio-pubic branches were fused, there was visible a spheroidal swelling and one less characteristic in the opposite side. Last year Van Neck of Brussells published the pathologic findings in two similar cases in which he says: "the bone tissue and the cartilage in the zone of the enchondral ossification had signs of an ordinary inflammatory process." The author believes that this alteration belongs to the same class as coxa plana and Osgood-Schlatter disease. Delitala in 1922 was the first to show this peculiar location in a patient affected with coxa vara. Valtancoli states that the ischial branch of the pelvis is entirely ossified at the age of eight years. He has also noticed the coincidence of a delay in the union in cases of congenital dislocation of the hip, and when this joint is involved with inflammatory process there is a premature ossification.—*Felipe Muro, M.D., Farmington, Mich.*

INJURIES TO THE MUSCULO-SPIRAL NERVE. W. Russell MacAusland and Andrew R. MacAusland. *The American Journal of the Medical Sciences*, January, 1925.

This paper considers injuries due to original trauma, or to pressure on the nerve from bony callus or scar. The anatomy of the nerve is reviewed.

The Symptomatology is discussed under the following headings:

Motor changes: The most important are wrist drop, loss of power of extension of the hand, and loss of supination when the forearm is extended. Sensory changes are inconstant. Pain is evident if the nerve is injured or compressed, and is most evident a few days after the injury. The clinical examination should determine if possible whether the nerve is completely divided or merely traumatized. Function may be lost through complete severance or through compression. All the muscles supplied by the musculo-spiral should be tested. If there is present a slight trace of movement, recovery may be expected. Electrical diagnosis: Faradic irritability, after ten to fourteen days, means that the nerve will recover spontaneously. With diminished Faradic irritability, a feeble galvanic contraction indicates nerve degeneration, while a brisk one is an indication for expectant treatment. The sensory examination should include the epicritic sense, the protopathic sense, and the deep sensibility. Injuries to the musculo-spiral may produce: (1) Complete loss of function through trauma, or (2) loss developing later, from pressure by callus or scar tissue. Complete division may result from fracture of adjacent bone or direct injury to the nerve; such cases should be sutured as soon as possible.

Three cases of operation on the nerve are reported, with details of the operative procedures:

1. A complete severance of the nerve with nerve suture four months after injury, followed by good return of function, both motor and sensory.

2. A case of compression of the nerve in scar, following a deep muscle injury operated upon two months after injury, with good recovery after freeing the nerve from scar tissue.

3. Compression of the nerve in callus and scar tissue after fracture of the humerus with non-union. This case was operated upon eighteen months after the injury, freeing the nerve from scar tissue and laying it in a new bed. A good functional recovery was achieved more than four years after date of injury.

The authors state that, in general, operative results have been satisfactory, with the prognosis better if the interval between injury and operation is short, but with a chance of complete recovery after a long period of paralysis, even after three and a half years. Establishment of continuity by end-to-end suture offers a greater chance of success than any other procedure, such as grafting, implantation, or transplantation of nerve. Open wounds over the musculo-spiral, accompanied by wrist drop, should be enlarged at once, and the nerve sutured, if divided. The same should be done in case of injury from a blow in which it seems probable that division has taken place.

In case of fracture, the fracture should first be reduced and exploration of the nerve done if paralysis persists after three or four months.

The authors give their own technique, approaching the nerve both from above and below the seat of injury, freshening the bulbous ends, or resecting swollen or constricted portions and suturing the sheath with linen. The nerve should be placed in a new non-scar tissue bed between layers of fat or muscle tissue. The elbow should be held in flexion, with wrist and fingers in hyperextension, for from five to six weeks. Massage and muscle training are begun when motion begins to return, which is usually in three or four months, with a year before restoration is complete.

Numerous methods of bridging too large a gap are mentioned. Results of nerve transplantation have not been encouraging. Resection of the humerus to allow approximation of the nerve endings is justifiable only in cases of ununited fractures complicated by division of the nerve. If the repair of the nerve is not possible or successful, tendon transplantation should be considered, the object being the restoration of muscle balance in the hand by transposing some of the flexors to the dorsum. The most suitable muscles for transplantation are the flexor carpi radialis, flexor carpi ulnaris and the pronator radii teres. The authors describe their own technique of transplanting tendons of the flexor carpi radialis and ulnaris, and anchoring them through the split tendons of all the extensors. Two case histories are given. Various methods of transplantation by other surgeons are then briefly reviewed. The pathology of nerve injuries and the reparative processes which follow them are described. An exhaustive review of the literature and a very extensive bibliography complete the article.

In conclusion: The nerve trunk may be crushed without damage to the sheath; may be completely divided; or power may be lost through involvement of the nerve in scar tissue or callus. Early recognition and treatment are very important. A perfect result may be expected from immediate suture. Intervention has given good results in cases of long standing, but chances of success are lessened after long paralysis. Simple freeing of the nerve is often the only procedure necessary. In cases of complete division of the nerve or where there is need to excise a portion of it because of fibrous formation, nerve suture is the most satisfactory procedure. If it fails or cannot be accomplished, tendon transplantation gives satisfactory results. After severance of a nerve, healing begins spontaneously. After nerve suture function develops in the same manner as spontaneous healing. After secondary suture sensibility returns early and muscle control usually begins in two to four months and is completed in six to nine months.

The article is well illustrated.—*Edward N. Reed, M.D., Ocean Park, Calif.*

Chronic Non-Tuberculous Arthritis of the Hip in the Adult. Duguet and Clavelin. *Revue de Chir.*, 1925, 44, 321.

Thirty cases are reported in patients from twenty to fifty years of age. The authors discuss briefly the relation of the age of onset to the type of lesion produced by infection or trauma. They classify the thirty cases as follows: Congenital subluxation 5; coxa vara 2; arthritis deformans 7; old osteochondritis 2; arthritis deformans associated with coxa vara or coxa valga 4; congenital lesions associated with osteochondritis 2; and osteochondritis associated with coxa vara 1.—*J. Albert Key, M.D., St. Louis.*

Osteochondritis of the Hip and Coxa Vara. Bellando-Randone and Reviglio. *Revue D'Orthopédie*, 1925, 32, 335.

A boy seven years of age began to limp after an attack of scarlet fever. The clinical picture was that of osteochondritis of the right hip, except that abduction was limited in both hips. A roentgenogram showed bilateral coxa vara with a flattened femoral head on the right. The patient was followed for five years. At the end of this time the gait was normal. There was, however, two centimeters shortening and slight atrophy of the right thigh, with some limitation of abduction and internal rotation in the right hip. On the right, the head of the femur was enlarged and flattened.—*J. Albert Key, M.D., St. Louis.*

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